Comparison of Visualization Techniques for Displaying Medication History to Older Adults

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ABSTRACT

Objective
This study aims to understand how older adults currently manage their medication information, and determine their preferences and their performance when using three different interaction techniques for viewing it online: a weekly calendar, a list, and a bar chart.
Design
Thirty subjects aged 55 or older, who had taken five or more prescription medications in the past two years, and were able to use a computer, participated in the study.
Measurements
Qualitative surveys and guided interviews provided information about participants' ability to remember details about medications, how they currently manage medication information, and how and with whom they share it. Quantitative measures were made of participants' speed and accuracy in using one of the three techniques to which they were assigned in completing basic information-seeking tasks, and their average ranking of all three techniques, as well as their own current method of information management.
Results
Participants usually share medication information with doctors and families, and tend to share details about their prescriptions (such as dose or purpose) or side effects they personally experienced. The three electronic management techniques all outperformed and were favored over participants' own manual methods. The list and bar chart methods were the overall favorites and top performers; however, the best technique to use depended on the type of task.
Conclusion
Electronic medication information management techniques show promise for helping adults remember and share key details of their medication histories.

I. INTRODUCTION

The movement towards electronic medical records (EMRs) and personal electronic health records (PHRs) has recently gained momentum in the United States. EMRs are generally considered to be information used in the context of healthcare providers and organizations, while PHRs are often the domain of consumers and individuals. Many studies have addressed the information needs of healthcare providers in the construction of EMRs and PHRs. Fewer studies, however, look at the information needs of patients and consumers.(1) Three factors are converging to motivate a more customer-centered approach to health information: near universal penetration of information technology in homes and work places, strong demands by patients to have access to their own health information and participate with health care professionals in healthcare decision-making and management, and spiraling healthcare costs. These factors are helping drive development of Personal Health Record (PHR) systems.

Older adults have multiple information management needs that are uncommon to younger, healthier generations. Among these is the management of prescription drug information, which can require a significant amount of time and effort. People with severe chronic conditions or those who are simply taking multiple medications as they age find the management of sometimes complex drug regimens a challenge. How do older adults manage their prescription drug information currently, and how would they like to do it? What role could an online system play in the personal management of medication information? How would this system support older adults wishing to share their medication information with others? In this paper, medication information refers to the name of a drug being taken, drug dosage, frequency of administration, time period of prescription, prescribing physician, pharmacy filling prescription, and side effects of the drug. Related information includes medication history of the participant, their medical record, and side effects of medications that they have personally experienced.

This paper focuses on developing guidelines for appropriate human computer interaction techniques for PHR interactions. It presents results from a study testing three different visual interaction techniques connected to a pilot online medication information management system, and survey results about the participants' medication information use and sharing.

II. BACKGROUND

In a 2003 national survey, 90% of seniors (aged 65 and older) reported taking at least one prescription drug, and of those, nearly half used five or more prescription drugs. In the same survey, more than 50% of seniors using more than one prescription drug also reported having multiple prescribing physicians, and 30% reported going to more than one pharmacy to obtain their prescriptions.(2) The diversity of prescribing physicians, pharmacists, the potential for drug interactions, and the sheer volume of drug prescriptions among American seniors suggests that people in this age group have a tremendous amount of information to manage related to their prescriptions. Without adequate information about a patient's existing prescriptions and medication history, medication errors leading to complications can result from these fragmented interactions.(3) Experience with electronic physician order entry systems and electronic prescribing has already shown that being able to track and share basic medication information between providers enhances communication between patients and their doctors, among medical professionals themselves, and increases patient safety.(1,4-6) However, a critical source of information on a patient's medication history remains the patient themselves.

Most published literature on medication management focuses on adherence to medication regimens, and more recently, on management of prescription medication costs. Literature on the topic of medication *information* management is sparse. For purposes of this paper, the term medication information management is defined as the methods and artifacts by which people organize and retrieve information such as medication names, indications, side-effects, contraindications, dosing regimens, and medication history. Some indications of how people currently manage information relating to their medication dosing schedule can be found in published studies. For example, in a 1992 study of 179 adults aged 65 and older who were recently discharged from hospitals, Conn and Taylor found that the majority of subjects (41%) used the location of pill bottles as a reminder of their dosing regimen, followed by use of a routine to associate a particular time of day or activity with dosing (22%), a timed pill box (12%), and reminders from another person (11%).(7) A 2006 study by Hutchinson and colleagues found calendars the most common reminder artifact used by older people for managing a medication regimen (98%), followed by pill boxes (69%) and bottle locations (21%, N=52).(8) Subjects in both studies could report more than one strategy for remembering their dosing regimens.

These simple methods are important in helping people keep track of their drug regimens. In terms of remembering a medication history, however, reminder artifacts become even more critical. Without any reminder artifacts such as lists or pill bottles, al Mahdy and Seymour found that only 10% of subjects were able to give a complete account of their drugs, which included information such as name, dosage, reason the drug was taken, and dosing regimen.(9) Recall of current drug information was significantly better in a study by Spiers and colleagues, who noted that more than half of all seniors surveyed recalled their medication, dosage, dosing regimen, what to do if a dose is missed, and the purpose of the medication.(10) No questions were asked about medication history in the study by Spiers and colleagues. The individual's management of their own medication history is an unexplored topic within published literature.

A. Privacy

Medication information involves an individual's private health information, some of which can be personally sensitive. Privacy concerns become even more important when information could be potentially embarrassing or personally damaging if released. Many people are concerned about keeping private medications to treat conditions which carry social stigma, such as mental illnesses. In a study of blood donors, Melanson and colleagues found that 11% of their sample did not report medications found in their donated blood through testing, and that unreported medications were consistently anti-depressants.(11) Older adults, in particular, are concerned about release of depression medication information. Elders are more likely to dismiss symptoms of depression, and experience powerful stigma associated with being depressed.(12,13)

B. Use of Information Technologies by Older Adults

If PHRs were available, it is unknown whether or not older adults would use them at all, much less use them to manage medication information. However, there is good evidence that seniors will use computers and the internet to find health information. The Center for the Digital Future at USC Annenberg found that the percentage of older American internet users has increased steadily over the last four years, to 67% of those surveyed between the ages of 55 and 65, and 38% of those over 65.(14) A 1998 SeniorNet study showed that finding health information is a key reason why older adults go online.(15) It is less clear whether older adults will use these technologies for PHRs. A recent survey conducted for the Markle Foundation reported that two-thirds of Americans across the socio-economic spectrum are interested in accessing their own health information electronically.(16) PHRs allow people to manage their health information, sometimes in conjunction with their healthcare providers or healthcare payers' medical health record systems.(6,17-21) In the United States, most internet-accessible PHR-like tools are available exclusively through large healthcare delivery networks. Perhaps only 250,000 Americans (less than 10% of the United States population) have access to them.(1) The proportion of these users who are older adults is unknown. A recent AARP Public Policy Institute report reviewed 24 PHR systems and found that although adoption is currently low, there is considerable interest on the part of patients as well as providers.(22)

A growing body of literature exists on how older adults interact with information technologies, particularly the internet. Studies in Sweden and Australia indicate that with appropriate training and support, older adults develop extremely positive attitudes toward new technologies (especially the internet).(23) However, older users may have difficulty using computer-based technologies, and clearly PHR designs must pay careful attention to age-related abilities and preferences, including:

- Unfamiliarity with new technologies and user interface conventions;
- Decreased motor coordination skills, such as those needed to use a mouse and click on links;
- Difficulty reading small print (font sizes of 12 points or larger are recommended for older internet users);
- Difficulty retaining information in short-term memory, which affects older users' ability to comprehend long web pages, use dense navigation systems, and remember fine grained usage details; and
- Decreased cognitive skills, causing difficulty making sense of content. (14,24-27)

Usability is crucial to the adoption and effective use of all types of information technology innovations.(28,29) For software, usability is determined by the human-computer interface, and there is growing attention to usability testing as part of return-on-investment decisions.(30,31) There are no studies of user interface designs applied to PHRs for the elderly. Besides basic usability guidelines for the elderly, little research has been performed regarding appropriate choices of interaction techniques. The two primary approaches in existing PHR systems are based on simple lists or on time-based approaches such as calendars. While lists may be the most commonly used current method, time has been shown to be useful as an organizing scheme for life events in empirical studies of personal health history designs.(32,33) In a study of breast cancer patients, Pratt found that being able to integrate personal, professional and health related information, especially for scheduling purposes, was very important.(34) This study evaluates a list approach, and two time-based approaches: a calendar, and a graphical bar chart which provides a convenient overview of the time dimension of a medication history.

III. METHODS

Because so little is known about how older adults manage their medication information, this study was designed to survey the medication management behavior of a small population, and to help in establishing some basic guidelines for user interface design for this application. The sample size of thirty participants was planned to provide sufficient statistical power to distinguish performance differences between three computer-based visual interaction techniques for presenting PHR medication information. The study population includes adults aged 55 or older, who have taken five or more different prescription medications in the past two years (not necessarily simultaneously). Study participants were required to have used a computer, although only basic computing experience was necessary (such as the ability to use a mouse, and browse the internet). The sample obtained for the study was a convenience sample, and relied on informational emails sent to the University of North Carolina-Chapel Hill (UNC-CH) community, and flyers posted at local retirement communities. The study was approved by the UNC Institutional Review Board (IRB).

The survey consisted of an introduction and seven parts as seen in Table 1. The complete survey is available at [http://www.ils.unc.edu/bmh/pubs/phr/Tasks_Interviews_2006-04-18.TLL.doc]. The survey instrument was pilot-tested on 10 subjects prior to finalization and beginning data collection. The study was performed in private meeting rooms on the university campus and at two retirement communities in the Chapel Hill, North Carolina area. Participants completed the study over two one-hour sessions. The study research assistant interviewed each participant and recorded their responses on a paper copy of the survey form, entered the data into Microsoft Excel spreadsheets, and transferred the data to SAS (SAS Institute Inc.,Cary NC) for further statistical analysis.

Table 1. Study Session Sequence

Introduction to Study and IRB consent
I. Survey: Demographic Questions
II. Task Test 1: Current Method
III. Survey: Information Sharing
IV. Survey: Medication Information
V. Interaction Technique: Demonstration and Training
VI. Task Test 2: Interaction Technique
VII. Structured Interviews

Participants in the study first received information about the study, their participation in it, and then began the formal study by answering initial demographic questions. Next, they completed a set of medication information recall tasks (Task Test 1), using their regular method (such as memory, lists, or pill bottles as available) to answer questions about their current and past medication use. After Task Test 1, they answered questions about how they shared medication history information, and how they store, access and use their medication information. They were then introduced to the visual interaction technique assigned to them (either calendar, bar chart, or list), and were trained to use it with a fictitious person’s medication history. The three interfaces are shown in Figures 1, 2, and 3. The same system used in the experiment, with the training case, is available as an online demonstration [http://neoref.ils.unc.edu/phr2/, use login name of "mjane"]. After successfully completing training on this interface, participants completed the same medication information tasks as in Task Test I using the interface, using the record of a different fictitious subject, ssmith. Finally, they were introduced to the other two interaction techniques, answered survey questions about the interface they used, and compared the interfaces to each other and to their regular way of handling medication information. The tasks in Task Tests were chosen based on the pilot survey, which indicated what information participants thought was the most important to recall, and which recall tasks they did the most frequently.

Figure 1. Calendar Interface

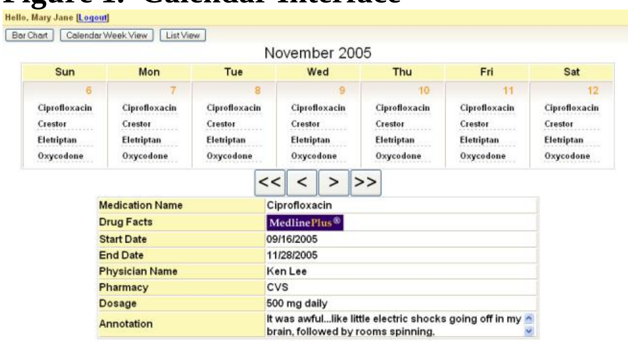


Figure 2. List Interface.

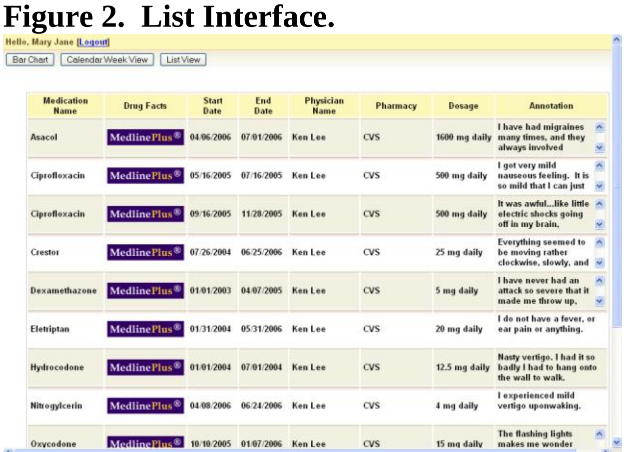
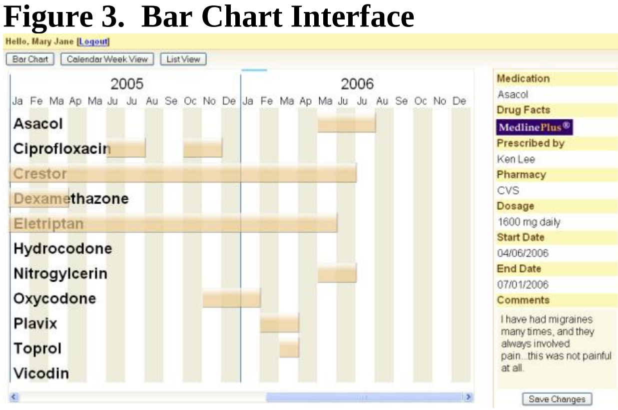


Figure 3. Bar Chart Interface



Responses to the survey questions in sections III and IV could be one of three answer types: numeric, categorical (pre-coded), or free text (post-coded). Free text responses were reviewed after the survey to produce a post-coded set of fixed answer categories for the questions. An effort was made to standardize the coding schemes for questions that had similar answer domains, so that they used the same coding scheme when possible. A complete listing of the possible coded answers for each question in the survey, as well as the free text responses is available online [http://www.ils.unc.edu/bmh/pubs/phr/Survey%20Question%20Codes_12-10.doc].

Descriptive statistics are used to report results from the surveys. The results from the task tests include completion speed for individual tasks, and the participant's accuracy when completing the task. Speed and accuracy are used to analyze mean differences in task completion times between the visual interface techniques, as well as compare accuracy between the computer based techniques and the participant's own manual method.

IV. RESULTS

A. Demographics

Table 2 summarizes the survey results from the demographic questions the participants were asked in the first part of the study.

Table 2. Participant Demographics

Number of Participants	**30**
Age	Mean=67.5; Min=55; Max=86
Gender	30% Male (N=9), 70% Female (N=21)
Do you have access to a personal computer connected to the internet in your home?	97% Yes (N=29), 3% No (N=1)
How many hours do you use the computer in a typical day?	Mean = 3.9
How many medications are you currently taking?	Mean = 6.0
What is the maximum number of medications you have taken at the same time during the past 12 months.	Mean = 6.5

B. Medication Information Sharing

Questions about information sharing were posed in two formats in the survey: critical incident recall, and a recent complete history review. Critical incident questions were focused on the last time the participant shared medication information. The complete history review asked them to list all medication information sharing events during the last three years in their answers. The results from the complete history reviews closely matched those reported in the critical incident recall, but provided additional details as well as responses to questions that tested the participants' memory of events in the more distant past. Because the recent history reviews were in agreement with the critical incident results and more complete, discussion and analysis in this paper are based on the recent complete history reviews.

The survey found that people primarily share their medication information with health care professionals (63%). They also frequently share their information with family (35%). All other responses comprised only 1% of the answers. Participants share medication information, such as drug name, dosage, and frequency, (47%) and medication side effects that they have experienced or heard about (32%). Information is almost always shared either verbally (54%) or through a paper list (35%). Most of the sharing occurred in their doctor's office (50%) or a hospital (10%), with the rest evenly split between home (20%) and outside the home in a non-medical setting (20%). On average, participants shared their medication information with someone else 39 times each year.

C. Survey Results: Medication Information Management

People were generally happy with how they currently maintained their medication information. Eighty-seven percent were satisfied with how their medication information is kept currently. Ninety percent were satisfied with their ability to share their medication information consistently and accurately. Though satisfied with the way they currently managed their medication information, when asked if there were things they would change, they listed having information available electronically (26%), having a complete and accurate record (13%), having reminders about taking medication (6%), and having portable information (3%). A follow-up question asked "How would these changes help you?" Participants responded that the suggested changes would improve organization and recall of the information (48%), make it easier to share information with others (26%), provide reminders for taking/refilling medications (17%), and help avoid drug interactions or side-effects (9%). Participants were then asked "How important is it to you to keep annotations about your health related to your medication history?" Forty-three percent said it was very important, 37% said somewhat important, and only 20% said it was not important. Several of the participants who said that it was very important to be able to keep annotations nonetheless indicated that they did not keep them.

Participants generally wanted to save the same information they wanted to share, as seen in table 3. The information they actually reported sharing in part III of the study correlated well with what they said they wanted to share. Two types of information were shared more often than projected based on their "want to share" responses: medication history(presumably because the health care providers required that this information be provided on visits), and topics that people were more socially prone to talk about (e.g., side effects, how to purchase drugs, what alternatives were available). Less information was "actually shared" about drug prescriptions, than was projected by the "want to share" responses.

Table 3. Participant survey results on their sharing of personal health information.

Answer	Want to Save	Want to Share	Actually Shared
Nothing	14%	9%	0%
Drug Prescription	67%	56%	47%
Medication History	0%	2%	2%
Reasons for Taking	14%	16%	0%
Side Effects	6%	12%	32%
Medical History	0%	5%	11%
Info on alternatives	0%	0%	2%
Info on access/purchasing	0%	0%	7%

There was also information participants did not want to share. The information they most wanted to keep private was medication information, such as name of medication, dosage, and frequency (67%, 6 respondents). Medication history (11%), medical history (e.g., medication conditions, 11%) and side effects they personally experienced (11%) were each mentioned once. The participants kept track of their medication information mainly by lists (39%), memory (17%), or pill bottles (14%). They updated their medication information when they had a new or renewed prescription (47%), on a semi-annual or annual basis (27%), whenever they used their medication history information (13%), or when their storage system (drawer, pill bottles, post-it notes) ran out of space (3%). Ten percent, however, did not save anything. The vast majority of participants (80%) update their own medication history, with the only other significant category being spouses (wives maintaining husbands records) at 10%.

D. Task Test 1 results

Participants were asked a series of questions (Table 4) about the second drug from a list of three recent medications they were asked to provide. They were also asked questions about their use of the medication codeine during the past 10 years. Codeine was used in the survey because many participants were likely to have taken it at some point, and it would serve as a more difficult memory test than one of their more recently used medications. The accuracy of the participant's answers were rated by the experimenters, and scored categorically as one of three responses: (1) able to answer the question completely; (2) able to answer partially (perhaps knowing only some side effects, or not knowing the start date of the medication); and (3) unable to answer. Accuracy ratings based primarily on the completeness of the participants answers were used because absolute truth for some questions was not known, for instance if the participant did not have complete information on previous medications. Ratings were averaged across all observers, and are reported in Table 4.

Table 4. Accuracy of Participants' Responses on Task Test 1.

Task Questions	Able to answer (Mean)
1. Duration	
a. Start taking drug x?	1.53
b. Stop taking drug x?	1.00
c. Drug x dosage?	1.53
2. Med Overlap	
Drugs taken concurrently?	1.17
3. Remembering	
Taken Codeine?	1.57
4. Side effects	
a. Any side effects from Codeine?	1.33
b. What are the side effects of x?	2.10

Values are coded as 1=completely accurate, 2=partially completely accurate, 3=incomplete or unable to answer.

Participants generally did a good job of remembering when they stopped taking drug X, primarily because most of them were still taking it. They did less well remembering when they started taking it (most often they did not know the month they started taking it, even if they remembered the year), or what the dosage was when they started taking it. Most participants remembered other drugs they took concurrently with their drug X. On average, they were only able to provide partial information about their use of codeine. From the experimenter's observations, there were three primary factors effecting whether the participants remembered taking codeine and what they remembered: if they had a particularly memorable side-effect; if they knew that codeine was a part of other drugs they had taken; and how long ago they had taken it. They did a little better remembering the side effects they experienced from codeine (if any). They were the least able to describe the possible side effects of their medication X, and on average provided partial information to no information.

A further analysis was conducted to see if there were differences in the accuracy of participants' responses depending on the memory artifact they used. The average scores by memory artifact are given in Table 5. Pill bottles or pharmacy printouts always provided complete and accurate information, as would be expected. Lists were not as accurate. Often the information recorded by the person was out of date or incomplete (for instance, lists were often missing the start date of a prescription), resulting in lists being between fully accurate and partially accurate. How accurate lists were also depended on the source of the information recorded. When the participants depended on their memory for their information recall, their lists were usually only partially accurate (most results were between 1.5 and 2.5). Two factors that appear to affect this were the number of medications they were on and if their medications had recently changed, or changed frequently. From the participant's responses, it appeared that they most commonly used their memory for recall tasks, except for when their memory was unsure and they had available external artifacts (lists or pill bottles). While the external records were more accurate, most participants only kept them for the past year or two.

Table 5. Accuracy of Task Test 1 responses broken out by artifact used.

Task Questions	Person's Memory	Person's List	Pill Bottles or Pharmacy Printouts	Overall
1. Duration				
a. Start taking drug x?	1.50 (n=26)	2.00 (n=3)	1.00 (n=1)	1.53
b. Stop taking drug x?	1.00 (n=30)	(n=0)	(n=0)	1.00
c. Drug x dosage?	1.79 (n=19)	1.10 (n=10)	1.00 (n=1)	1.53
2. Med Overlap				
Drugs taken concurrently?	1.17 (n=23)	1.00 (n=6)	1.00 (n=1)	1.17
3. Remembering				
Taken Codeine?	1.58 (n=29)	(n=0)	1.00 (n=1)	1.57
4. Side effects				
a. Any side effects from Codeine?	1.37 (n=30)	(n=0)	(n=0)	1.37
b. What are the side effects of x?	2.50 (n=30)	(n=0)	(n=0)	2.50

The right column is overall average of all three types. Values are coded as 1=completely accurate, 2=partially completely accurate, 3=incomplete or unable to answer.

E. Task Test 2 results

The quantitative results from Task 2, where participants used one of the visualization techniques to find a fictitious person's medication history information, are reported in Tables 6 and 7 below. Several important results are evident. Most importantly, both the speed and accuracy of the retrieval results depend on the visualization technique and on the task.

To distinguish which of the computer based visualization techniques performed the best for which tasks, tests of mean differences using analysis of variance were computed for each task (SAS GLM). Pair-wise differences between the mean task completion times were computed for the three different visualization techniques (Table 6). The techniques that were statistically significantly the fastest (Table 6) are indicated in boldface font ($P < 0.05$). The calendar technique was the slowest of the three for each of the tasks. However, it was not always statistically significantly slower because of its large variance. The large variance was partly due to some participants performing reasonably fast with the technique (on par with the other two techniques), while other participants had a very difficult time with the technique and performed very slowly. From observation of the subjects this was primarily due to difficulties in navigating through the calendar to find information from time periods not displayed on the current screen.

Table 6. Task Test 2 mean completion speed by visualization technique.

Task Questions **Speed Analysis**	Computer Based **Calendar** (N=10)	Computer Based **List** (N=10)	Computer Based **Bar Chart** (N=10)
1. Duration			
a. Start taking drug x?	0:01:02	**0:00:06**	0:00:15
b. Stop taking drug x?	0:00:23	**0:00:03**	0:00:07
c. Drug x dosage?	0:00:14	0:00:10	0:00:16
2. Med Overlap			
Drugs taken concurrently?	0:01:00	0:01:02	**0:00:24**
3. Remembering			
Taken Codeine?	0:01:29	**0:00:18**	**0:00:36**
4. Side effects			
a. Any side effects from Codeine?	0:02:28	**0:00:47**	**0:01:21**
b. What are the side effects of x?	0:00:48	**0:00:22**	**0:00:35**

For the accuracy analysis, the accuracy results of the participants own method from Task Test I were included along with the accuracy results of the computer based visualizations. A test of mean differences of accuracy values between techniques using analysis of variance was performed (SAS GLM) and the results are shown in Table 7. There were clear best performing interactions for answering the duration questions (1a, 1b, and 1c) and the remembering about taking Codeine (3), all of which were statistically significant, except for 1c. An additional set of ANOVA test (SAS GENMOD) was performed to compare the mean of all the computer based techniques taken together versus the manual technique, for each of the tasks. Results were statistically significant for only two of these tests. For 4a (recalling a particular side effect of a medication) the participant's manual method was more accurate, while for 4b (remembering all the side effects of a past medication) the computer based interaction techniques produced more accurate results than the participant's manual method. As found in the speed analysis, the technique that performs the best depends on the task. The person's manual method may perform as well as the computer based visualization interfaces (as for tasks 1b and 2a) or even better than them (4a). Complete statistical analysis details are available at http://ils.unc.edu/bmh/pubs/phr/statistics/.

Table 7. Mean accuracy values for the three visualization methods and the manual human memory based system.

Task Questions Accuracy Analysis	Computer Based Calendar (N=10)	Computer Based List (N=10)	Computer Based Bar Chart (N=10)	Personal Memory, Lists, Pill Bottles (N=30)
1. Duration				
a. Start taking drug x?	1.30	**1.00**	1.60	1.53
b. Stop taking drug x?	1.20	**1.00**	1.40	**1.00**
c. Drug x dosage?	1.20	1.20	1.00	1.53
2. Med Overlap				
Drugs taken concurrently?	1.10	1.60	1.30	1.17
3. Remembering				
Taken Codeine?	**1.00**	**1.00**	1.40	1.57
4. Side effects				
a. Any side effects from Codeine?	1.60	1.60	1.60	**1.37***
b. What are the side effects of x?	**1.60***	**1.60***	**1.80***	2.50

Participants responses are coded as 1=completely accurate, 2=partially completely accurate, 3=incomplete or unable to answer. Bold values indicate statistically significant superior results. Asterisk values indicate statistically significant differences in comparisons between groups (all computer based techniques together versus human based manual methods).

While on average the accuracy of responses based on human memory or artifacts was less than that of the computer based techniques, for some tasks the human methods were as accurate as or more accurate than at least some of the computer techniques. Since the complete and fully accurate medication history information was available in all of the computer visualizations, any failure to find this information is a direct result of a poor human computer interaction technique for the study population for that task. These situations are easily identified from Table 7, in cases where the accuracy of the computer based technique is substantially greater than 1.0. For instance, in determining the exact start date of a particular drug, participants demonstrated poorer accuracy with the bar chart interaction compared to the other computer based techniques and manual recall. Similarly, their performance was worse with the calendar view when answering questions about concurrent drug usage when compared to all other techniques.

F. Participant ratings comparing their computer techniques to their manual method

After participants had completed task test 2, they were asked to rate how the computer interface they tested compared to their standard method of information recall for their medication history (which they used in task test 1). The results are shown in Table 8. Almost universally, the participants felt that the computer-based technique they used was faster than their usual method, and that having the information online made it easier to remember medication information than using their usual method. They also indicated that having the direct link to the Medline information for the drug was effective. When contrasting their manual method versus the computer-based visualization technique, the computer-based techniques were always rated as superior. These results were independent of technique, with all the computer-based techniques receiving nearly identical top ratings. Participant's ratings matched their performance results in the speed analysis, where computer based techniques performed faster and were evaluated as superior.

Table 8. Participant ratings of computer-based visualizations.

Question	Calendar	List	Bar Chart	Overall Mean
How much faster do you think you were at completing the tasks using the computer visualization, as opposed to your usual method?	4.7	4.6	4.5	4.6
How effective was having a direct link to information like Medline database as a way for you to look up additional information about medications?	5.0	4.9	4.6	4.8
Would having instructions your doctor or pharmacist gave you, or having your own notes available online make it easier or harder for you to remember these things than your current system	4.5	4.6	4.8	4.6

Response choices for the three questions using Likert scales. Responses for the first question were 1= slower, 2=somewhat slower, 3=about the same, 4=somewhat faster, 5=faster. Response choices for the second question were 1= ineffective, 2=somewhat ineffective, 3=about the same, 4=somewhat effective, 5=effective. Response choices for the third question were 1= harder, 2=somewhat harder, 3=about the same, 4=somewhat easier, 5=easier. The rightmost column is the mean of all three methods.

G. Experimenter observations of computer-based methods

The experimenter recorded observations of the participants' use of the visualization techniques in Task Test II. From these observations, comments about problems the participants experienced when using particular interaction techniques were extracted. The resulting comments were individually analyzed and then classified. The classification codes and the number of participants who had difficulty with these activities are shown in Table 9.

Table 9. Experimenter observation of participant difficulties using computer-based visualizations.

Coded Comments	Calendar	List	Bar Chart
Didn't use scrolling properly	4	4	1
Forgets to click on medication names	4	0	2
Didn't remember to check Medline entry	2	0	2
Had difficulty clicking on targets	1	0	0

Numbers in columns are counts of times the experimenter noted participants having problems using the visualization. Each instance was later coded into the categories shown in table rows.

Participants using the calendar interface experienced the most problems, primarily due to difficulties navigating to time periods not shown on the current screen. Users of all three interfaces experienced difficulty in scrolling through text in the comments textbox. This problem occurred most often with the list interface, which had the smallest size comments text box because of the amount of information displayed on the screen. Users also forgot to click on information, especially when using the calendar interface, perhaps being overloaded from managing the much larger number of navigation actions.

H. Participant rankings comparing all methods

After the participants tried all the visual interaction techniques, they were asked to rank order the visualization techniques and their own manual method from 1-4 (1 being the best). Rankings were given for five specific types of tasks. Similar to the speed and accuracy measures, the participants' rankings also indicated that their most preferred interaction technique depended on task. The bar chart was the clear favorite for determining what medications had been taken at the same time (overlap). The list was the most convenient for recalling the side effects of medications, most likely due its compact presentation, which allowed display of almost all medication information in a single screen. In other tasks, the list and bar chart were ranked comparably and always preferred over the calendar. In general the bar chart and list were the top choices, followed by the calendar, followed by the participants own manual method. The mean ranking values, averaged across all participants, are summarized in Table 10.

Table 10. Mean participant rankings of computer based visualizations and their own method for different tasks.

Task Ranked	Calendar	List	Bar Chart	Own Method
Ranking the three computer presentations and your own method overall from best to worst	2.60	1.67	1.93	3.53
Determining how long you took a particular medication	2.57	1.77	1.67	3.77
Remembering what other medications you took at the same time as another drug	2.37	2.47	1.43	3.57
Remembering whether or not you have taken a specific drug (such as Codeine) in the past	2.78	1.57	1.63	3.75
Recalling side effects for a specific drug	2.52	1.40	2.03	3.68
Overall, ranking the three presentations and your own method as a way of providing a history of your medications to another person	2.58	1.70	1.78	3.80

I. Participants' comments on interaction techniques

After ranking the techniques, participants provided general comments about each of the techniques for the tasks listed in Table 10. These comments were then individually reviewed, and categorized into coded responses. The resulting responses were divided into positive and negative comments. The list of coded responses and the number of times the response occurred are shown in Tables 11 (negative) and 12 (positive).

Table 11. Negative coded participant responses about computer-based visualizations.

Negative	Calendar	List	Bar Chart	Own Method
Too many interactions	29	3	12	0
Lack of an overview/big picture, difficult to navigate	24	3	4	1
Dislike from personal layout preference	12	10	6	0
Too much info	3	5	2	0
Difficult to see overlap of drugs	0	11	0	0
Difficult to see what you are currently taking	0	6	0	0
Difficult to see list of all medications	2	0	1	0
Dislike horizontal scrolling	0	1	4	0
Doesn’t contain day or week-level information	0	0	2	0
Can’t provide specific details about medication history (mainly applied to own method)	0	0	0	41
Information provided may be incorrect because I did not remember it correctly	0	0	0	5
Would take too long to find information	0	0	0	10
Prefer actual dates to graphic representation of dates	0	0	1	0

In some cases a single comment produced more than one coded response, thus comment totals may be higher than the number of cases (30).

Table 12. Positive coded participant responses about computer-based visualizations.

Positive Comments	Calendar	List	Bar Chart	Own Method
Like the fine details (day/week)	13	0	0	0
Like information centered on the screen	6	0	0	0
Like reading down as opposed to across	0	0	0	0
Like placement of the drug information box	0	0	2	0
Easy to compare information for multiple drugs	1	6	5	0
Big picture/overview, no horizontal scrolling, fits one screen	2	28	24	0
Like reading left to right	0	3	0	0
Convenient access to all information	1	20	20	1
Like alphabetical ordering of drug names	0	1	0	0
No computer required for access	0	0	0	7
Can keep on person	0	0	0	6
Not limited to prescription meds	0	0	0	1
Like horizontal scrolling	0	0	2	0
Like interactivity of scrolling	0	0	0	0
Able to see drug overlap easily	2	0	7	0
Like graphic representation of dates	0	0	5	0
Would compliment other visualizations if available together	2	1	1	0
Large print size easier to see	0	0	3	0
Quicker than using a computer	0	0	0	6
Medline links/comments easy to find	4	18	1	0

In some cases a single comment produced more than one coded response, thus comment totals may be higher than the number of cases (30).

The speed and accuracy results, combined with the participants' rankings provide overall summaries of which techniques are good for specific purposes. The participants' comments recorded in this section are helpful because they provide explanations for why particular aspects of the interaction techniques performed well, or performed poorly. Comments gleaned from this section as well as other participant comments and the experimenter's observations are summarized here.

1) Calendar

In order to display the medications currently prescribed on each calendar day, at a size sufficient for viewing by seniors requires displaying not more than one week at a time on current standard computer displays. Using week by week display also matches well with medication reminder applications. However, the result is that users have a very difficult time navigating at larger time scales (such as months and years) in order to answer questions like which drugs were taken at the same time as drug X. Twenty-nine of the thirty participants complained that the calendar interface required too many interactions to navigate. One way to compensate for this is to provide multiple zoom levels (i.e. dynamic zoomable interfaces allowing participants to change the timescale being viewed from days to months to years).(35) Versions of the calendar interface were tested in the pilot work that allowed dynamic shifts to larger time scales (monthly). This option was not preferred by pilot testers , who found it confusing, and indicated a preference for a simple fixed-scale interface of one week. In the experiment, many people commented positively on how the calendar interface focused the user's attention on the box containing all the medication's information, which was centered on the screen. A significant number of participants also indicated that they would like to see their medication history system integrated with their medication reminder system. An interface that would contain pictures of the pills they were to take, on a daily or weekly basis, would be useful to them. Overall, people who liked the calendar interface liked the simple view, or disliked it due to the poor navigational support at larger time scales. As a result, providing only the calendar interface could risk alienating a significant proportion of the audience.

2) List

This interface is closest to the artifact currently used by many people, in either written or computer-based formats. As a result it was familiar and comfortable to many participants. Its primary advantage is its concise format, which generally allows viewing of all medications on one screen. Searching for information was generally accomplished by viewing the main screen and involving at most one mouse click. Because of this efficiency, the list was a clear favorite for seeing "the big picture" and for its convenient navigation. Like many tabular visualizations, it could easily be extended to facilitate additional capabilities like sorting by columns (drugs, prescription dates, physician, and pharmacy) through a click on the column header. The main disadvantage of the list was that without a graphical interface showing the time periods for taking medications this information cannot be grasped as quickly as with a visual technique like the bar chart. Also, the very small size of the comment box made it difficult to see the complete comment, and required additional interactions to scroll through long comments. Despite being the most favored and best performing overall, ten subjects still indicated a personal dislike for this style of interface.

3) Bar Chart

The bar chart, along with the list technique, both performed the best and was liked the best. However, some people seemed a little less comfortable with this interface, as compared to the list. Twelve participants indicated that it required too many interactions. There were also six participants who didn't personally like the style of the interface, and four who did not like horizontal scrolling. On the positive side, it excelled in showing medication usage over long time frames, and in particular, showing medications that were taken simultaneously. If not used as the primary interface, it would be effective as a supplemental tool for when a graphical display was the most effective.

All of the interfaces could have benefited from additional functionality, like having a search function. Features such as a search function would have helped mitigate the difficulties inherent in the limited scale views of interfaces like the calendar.

4) Manual

Their own manual technique was the least favored by participants. They indicated that it did not provide complete or accurate information and often would take too long to retrieve the information even when available. On the other hand, several participants emphasized the advantage of not requiring a computer, and being able to keep the information on ones' person as advantages. This suggests that electronic methods should provide access through common portable internet capable devices, such as cell-phones and PDAs.

In addition to comments on the individual techniques, general comments and suggested improvements to the techniques were solicited from the participants. A complete summary of all these comments is available [[http://www.ils.unc.edu/bmh/pubs/phr/Survey%20Question%20Codes_12-10.doc]]. Overall, the most frequent comments fell into five main categories:

- Provide access to multiple interaction techniques dynamically, or find a way to provide a combination of techniques in a single visualization;
- Provide ways to output the information to other formats, including printing to paper, display on PDAs, or transferring via portable devices like memory sticks;
- Provide more customization of the visualizations and the amount of detail shown;
- Integrate medication history information with a medication reminder interface that shows more details on what medications the participant is currently taking, including specifics about pills such as daily dosage, a picture of the pill, etc.; and
- Allow the medication record and medical history from the PHR to automatically update the EMR in the doctor's office or health clinic, so that the patient does not have to fill out forms.

V. DISCUSSION AND CONCLUSIONS

Keeping complete and accurate medication information was clearly valued by the participants in this study. However, in most cases, people did not make the effort to maintain such information. The vast majority of people indicated they were satisfied with their current system of managing medication information (usually just remembering the information). In order for people to utilize a more accurate computer-based system, it must be convenient to use, and not require additional work by the user. This implies automatic exchange of PHR information, such as the loading of prescription information from pharmacies into the patient's medication history database, so that it would not need to be entered by hand, by the patients. To succeed, the visualization interface must be no more difficult to use than just remembering, and must be more accurate. While computer-based techniques could clearly be more accurate than the participant's memory, some of the techniques tested were not better in speed or accuracy for specific tasks, so the choice of interface technique is important. The information must be stored and generally accessible from the internet, so that it is available to users to view and to share in multiple contexts. Furthermore, to be as convenient as one's memory, and to be available in many different contexts, it must be available on many different interface devices including small portable devices like cell phones and PDAs. Other enhancements may still be necessary before electronic PHR systems become widely used. Some possibilities identified in this study include integration with medication reminder systems, and standardized exchange of PHR information so that patients could be saved from repeatedly filling out medication history forms.

The primary aim of this research was to help develop guidelines for interface design for personal health information in the area of medication history. Based on this study, major guidelines for visualizing personal health medication information should include:

- User interfaces should be designed with the known requirements of older adults in mind;

- Because the best choice of an interactive technique depends on the task, careful consideration should be given to the tasks involved and their importance;
- The best computer-based techniques were superior to human memory for recalling medication information details, both in accuracy and in speed.
- Human memory was better than some computer based techniques for some tasks, as well as being more convenient. Since there is not a single computer-based technique that is always better, designers must recognize that computer based techniques may not replace human memory for all medication information management tasks, and may be best utilized in a supplementary role, such as providing for the more accurate retrieval of less recent medication history.
- Information must be available from the internet so that it is instantaneously accessible by pharmacies, health care providers and institutions, patients and people with whom they may share information.
- The information must be displayable on different devices (web-based computers, PDAs, cellphones, printed paper, portable memory devices) to support access in different contexts.

The results strongly show that different tasks are performed faster and more accurately depending on the interface used. Further, dynamically configurable or changeable interfaces are becoming more common. It may be helpful to support multiple interaction techniques within one interface framework. However, it is also important to attempt to identify a single baseline presentation format that would be effective as the interface for a mass audience. Based on the results from this study, a list-like visualization would seem to be the best choice. The list or bar chart techniques were the consistently the best performers and the most preferred interfaces. The list usually performed as well or better than bar chart, with the exception of examining what past medications were taken concurrently. From the surveys, that particular task was not one of significant importance to users. Overall, the users seemed to slightly prefer the list over the bar chart. If multiple configurations were supported, it would be important to consider additionally including a calendar-based interface, because such an integrated system might better address the needs expressed by participants for having support for medication reminder systems.

It is important to remember that these results are based on a population of older adults taking multiple medications. Furthermore, the sample population is mainly from retirement centers in a highly educated college town, and is likely not representative of the older population as a whole. It would be useful to extend these results to larger segments of the population, including more diverse elderly populations as well as other groups with interests in medication tracking, such as those with chronic diseases, or families with small children.

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