Exploring the Accessibility and Appeal of Surface Computing for Older Adult Health Care Support

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ABSTRACT

This paper examines accessibility issues of surface computing with older adults and explores the appeal of surface computing for health care support. We present results from a study involving 20 older adults (age 60 to 88) performing gesture-based interactions on a multitouch surface. Older adults were able to successfully perform all actions on the surface computer, but some gestures that required two fingers (resize) and fine motor movement (rotate) were problematic. Ratings for ease of use and ease of performing each action as well as time required to figure out an action were similar to that of younger adults. Older adults reported that the surface computer was less intimidating, less frustrating, and less overwhelming than a traditional computer. The idea of using a surface computer for health care support was well-received by participants. We conclude with a discussion of design issues involving surface computing for older adults and use of this technology for health care.

Author Keywords

Health Care, Multitouch, Older Adults, Surface Computing

ACM Classification Keywords

H.5.2 User Interfaces: input devices and strategies

General Terms

Design, Experimentation, Human Factors

INTRODUCTION

Globally, the proportion of people over age 60 compared to younger population segments is growing at a rapid rate [21]. As we age, we experience an increase in health care issues that require ongoing medical attention. Managing medical care is challenging for everyone, but this is particularly difficult for older adults with declining physical, visual, hearing, or cognitive abilities. As medical practices begin to adopt digital patient record systems, communication of health care issues may be further complicated for older adults who are intimidated or overwhelmed by technology. The introduction of computer display systems into doctor-patient interaction presents opportunities to develop interfaces that are appropriate for older patients. While many older adults use traditional computer workstations, new interaction devices may be more suitable for the challenges inherent in older adulthood. Large multitouch surfaces seem particularly appropriate for older adults. Touch interaction is thought to have a low-barrier of entry. Interacting with digital media is accomplished in a direct and natural way without the encumbrance of a keyboard or mouse. We regularly use our bare hands to manipulate physical objects in the world, and touch interaction draws on this experience. The horizontal form factor of a tabletop is also familiar and affords sitting with other people while interacting with shared media simultaneously. Finally, projection permits enlarging visual information.

While these characteristics of surface computing seem well-suited for older populations, it is unclear how the physical nature of interaction, the setup of the device, and system novelty may affect older users. This paper examines the accessibility and appeal of surface technology for the older adult population within the context of health care support. In a laboratory study we assess the following: (1) whether the implementation of current surface gestures and interface elements match the expectations of older users, (2) how well older adults are able to physically perform actions on the multitouch surface, (3) the range of accessibility issues that may affect interaction, and (4) how older adults feel about using a surface computer for health care support. This study is part of a larger initiative to explore the role of surface computing in health care support for the older adult population. The long term goal for this research is to design and install a surface computer for use within the health care center of a retirement community; however, a critical first step in this process is to understand the appropriateness of surface computing for this context and population.

BACKGROUND

Surface Computing for Older Adults

Multitouch surface technology is increasingly available. The decreasing cost of projection technology along with the growing availability of multitouch software toolkits encourages research on surface computing. Commercially available multitouch technology (e.g., Microsoft and SMART Technologies) enables exploration of surface computing in settings outside of the lab such as offices, schools, retail stores, ho-

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tels, restaurants, and even hospitals. The proliferation of surface technology makes it important to understand how older adults, a large, growing, and yet relatively unaddressed user group, interact with and react to such technology.

While a range of research studies examine surface computing for general audiences, only a few studies examine the technology for older adults. Apted *et al.* created SharePic, a tabletop photo sharing application for older adults [3]. The older adult participants were able to learn to use SharePic and enjoyed using the tabletop display. The authors present a set of *a priori* principles for the design of a tabletop application for older adults, most of which focus on the task of photo sharing but some are applicable to other tabletop applications (e.g., focus on learnability and memorability). Similarly, Mahmud *et al.* designed a tabletop game for older adults [15]. They tested the tabletop game against a traditional board game and report that older adults found the tabletop game more engaging. Gabrielli *et al.* also created a single-user tabletop card game for older adults [8].

Identifying best practices for the design of surface computing and subsequent interaction is a persistent research question. A key contribution toward this effort is work by Wobbrock *et al.* that identifies a set of gestures for surface computing based on user expectations [22]. This work has important implications for accessibility of tabletop technology, as gesture-based interaction should be flexible and accommodate variations in touch input. The authors state, "...the number of fingers rarely matters and the fingers, palms, or edges of the hands can often be used interchangeably." Indeed, older users with declining physical abilities are likely to need a range of alternatives for interacting with a touch-sensitive display. Recent research has also examined reading text [16] and text entry [11] on a horizontal display, yet this work focuses on the abilities of younger users.

The Effects of Aging on Interaction

Whether or not a multitouch surface computer is an appropriate interaction device for older adults is a relatively unexplored question. To begin evaluating the potential advantages and drawbacks of the technology for this population, we present a brief review of challenges inherent in aging and the implications of each for surface computing.

One of the most notable characteristics of aging is a change in one's physical or motor ability. Older adults experience an overall slowing of movement as well as difficulty with fine motor activity and coordination [12]. Arthritis, a chronic and degenerative disease, is highly prevalent among older adults in the United States and is the leading cause of disability [13]. Physical limitations due to arthritis and general effects of aging stand to impact how well older adults are able to interact with a large, and perhaps physically demanding, multitouch surface. For example, are older adults comfortable reaching across the display? How do they manage fine motor movement on the touch-screen? Is touch interaction manageable for individuals with hand tremors?

Loss of or reduced vision is common for older adults, and 6.5 million Americans over the age of 65 have a severe visual impairment [14]. Enlarging visual information on a multitouch surface may be an advantage of the technology; however, software design should account for age-related change in visual abilities such as requiring more illumination for reading, decreased sensitivity to color and contrast, and issues with glare and depth perception [2]. Furthermore, it is currently unclear what text size is ideal for reading items at different locations on the surface and whether reading text on the horizontal display is problematic with bifocal lenses.

Loss of hearing is another common consequence of aging. About one-third of Americans between the age of 65 and 74 have severe hearing problems, and about half of Americans who are 85 and older have severe hearing loss [18]. Individuals with hearing loss rely on interpersonal cues to understand face-to-face conversation (i.e., watching the gestures and facial expressions of other people). How might the shared digital workspace support communication challenges due to hearing loss?

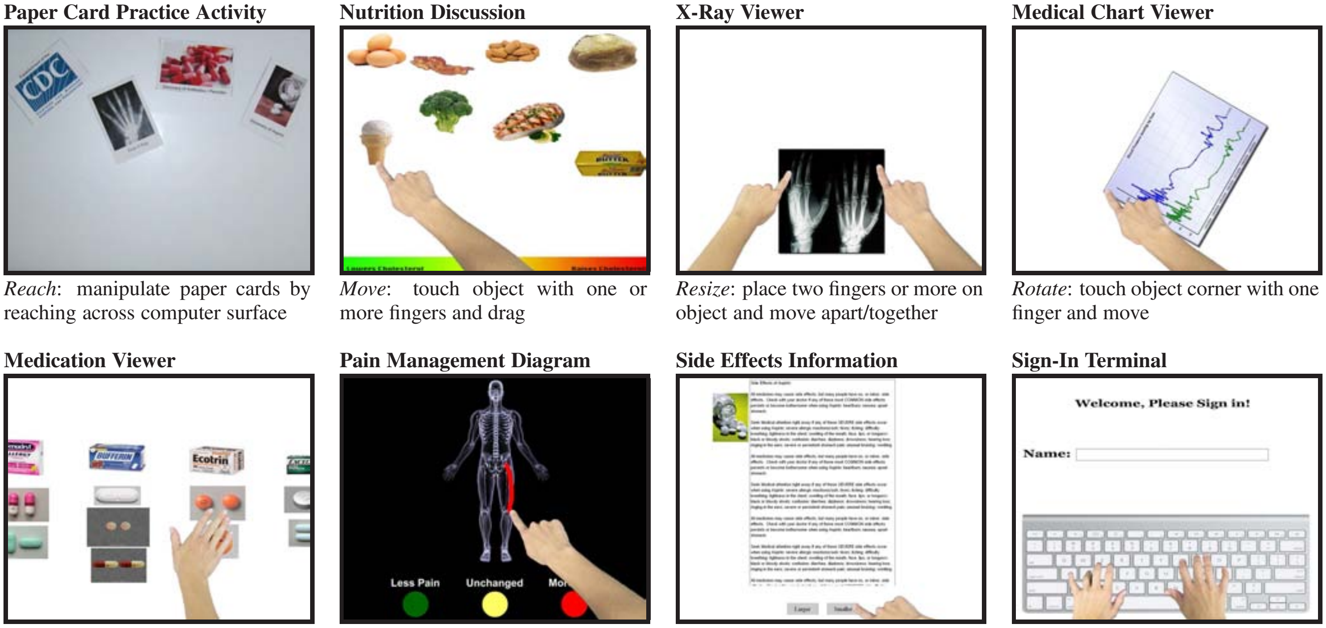
Finally, aging often results in a decline in memory. Changes in memory can be observed in how people encode new memories as well as the short-term maintenance and manipulation of information involved in working memory [6, 9]. One memory loss condition is Mild Cognitive Impairment (MCI), which effects approximately 5.4 million Americans over the age of 70 [1]. While aging in general decreases memory capabilities, people with MCI may more often misplace things, forget to go to important events and appointments, and have trouble coming up with desired words. General changes in memory necessitate that surface interaction is easy and quick to learn, a characteristic of surface technology that is assessed in the present study.

Technology for Health Care Support

As we grow older, we experience an increase in health care concerns. According to the Center for Disease Control (CDC), arthritis, heart disease, cancer, and diabetes are chief chronic diseases among older adults [5]. They are persistent conditions that require regular medical attention. Managing a chronic medical condition is a familiar yet challenging task for many older adults. Various computer display systems have been explored to help a patient self-manage their condition and care needs (e.g., [4]).

Many medical facilities are now transitioning to digital medical record systems. While this undoubtedly changes practices for health care teams [10], the introduction of digital record systems also affects medical interactions for patients [19]. For example, the doctor may have a computer workstation that displays the patient's medical history. This can change the interaction between physician and patient in multiple ways. For example, the physician must now attend to both patient and workstation and the patient may need to look over the doctor's shoulder to ensure the accuracy of their chart, verify a prescription, or view other data.

As electronic medical records become more integrated into the process of meeting with a doctor, there is a need to explore computer interfaces that facilitate sharing this information. A large multiuser display system seems inherently



Paper Card Practice Activity — *Reach*: manipulate paper cards by reaching across computer surface

Nutrition Discussion — *Move*: touch object with one or more fingers and drag

X-Ray Viewer — *Resize*: place two fingers or more on object and move apart/together

Medical Chart Viewer — *Rotate*: touch object corner with one finger and move

Medication Viewer — *Pan*: move one or more fingers horizontally across display

Pain Management Diagram — *Draw*: touch and move along surface with single finger

Side Effects Information — *Read Text*: touch buttons to increase and reduce text size

Sign-In Terminal — *Enter Text*: touch virtual keyboard keys with at least one finger

Figure 1. Basic surface interaction activities. All tasks focus on health care issues for older adults.

well-suited for this context and the older adult population. The form factor of a tabletop display provides medical staff and patients with a shared workspace where they may lay out and manipulate medical materials such as patient charts, x-ray images, and other visuals pertinent to conversation. In August 2009, this idea was put into practice at the Microsoft Medical Media Lab located within a Washington D.C. hospital. At this hospital, doctors may use a Microsoft Surface to share x-ray images with patients. Our research agenda involves installing a similar system at a health care center of a local retirement community. Results reported in this paper guide the design of the system we plan to deploy.

ACTIVITY DESIGN AND PROTOTYPE

We devised a series of basic activities to assess the following forms of interaction with the multitouch table: *select*, *move*, *resize*, *rotate*, *pan*, *draw*, *read text*, and *enter text*. We focus on these forms of interaction because they are pervasive in tabletop application design. The functionality and implementation of the gestures was guided by Wobbrock *et al.* [22]. For example, users expect to rotate an image by touching on a corner of the image and moving in a circular direction [22], therefore the *rotate* gesture in our study was implemented in this way. To assess the learnability and ease of performing each action, one gesture was presented per activity. Multiple gestures were not activated at the same time (e.g., users could not resize and rotate an image within the same activity).

We implemented seven basic applications using a DiamondTouch table [7] and the corresponding Flash development toolkit. This is a large (75 cm x 60 cm) top-projected capacitive tabletop system with a display resolution of 1280x1024. Figure 1 illustrates interface designs and gesture-based interaction for each activity. The design of each activity was intentionally minimalistic so that we were able to assess how much and what type of support older users would need to successfully perform each action. All tasks were set in the context of health care support. Ideas for tasks were derived from observations made during our ongoing field work, feedback from health care professionals, and our research team's prior experience designing technologies for health care support. The goal of each activity was to solicit a particular type of interaction from the participant in a task that was realistic but not too personal. For example, our field work and conversations with health care professionals revealed that older adults often forget which medications they are taking. To test the *pan* gesture, we presented participants with a basic application that allows them to look through a series of medicine brands and pill shapes. All activities were determined and designed in a similar fashion.

METHOD

We conducted a usability study involving 20 older adults (age 60 to 88; mean age=73.4, stdev=9.9; 13 females) to understand the accessibility and appeal of surface computing. All participants came into our laboratory to participate in the study. Table 1 presents background data for each older adult participant. In our sample of older adults, 18 had corrected vision, 10 had arthritis, and one person had severe hand tremors. To better understand the interactions of older adults, 10 young adults (age 19 to 26; mean age=20.7, stdev=2.2; 6 females) performed the same set of tasks and gave feedback on interaction. All young adults had prior experience with computers, but none owned or had extended experience with a multitouch device or tabletop. While we recruited younger adults without multitouch experience, we were unable to control for their prior exposure through media

Age	Gender	Computer Use	Own Computer	Touch-Screen Experience	Select	Move	Resize	Rotate	Pan	Draw	Read Text	Enter Text
60	M	Daily	PC	Single-touch	✓	✓	✓	✓	✓	✓	✓	✓
60	M	Yearly	None	Single-touch	✓	✓	✓	✓	✓	✓	✓	✓
61	F	Daily	PC	Single-touch, Multitouch	✓	✓	✓	✓	✓	✓	✓	✓
62	F	Daily	PC	Single-touch	✓	✓	✓	✓	Hint	✓	✓	✓
64	M	Daily	Both	Single-touch, Multitouch	✓	✓	✓	✓	✓	✓	✓	✓
65	F	Daily	PC	Single-touch	✓	✓	✓	✓	✓	✓	✓	✓
67	F	Daily	PC	Single-touch, Multitouch	✓	✓	Hint	✓	✓	✓	✓	✓
68	F	Daily	PC	Single-touch	✓	✓	✓	✓	Hint	Hint	✓	✓
70	F	Daily	Mac	Single-touch, Multitouch	✓	✓	✓	✓	✓	✓	✓	✓
72	F	Daily	Mac	Single-touch	✓	✓	Hint	✓	✓	✓	✓	✓
74	F	Daily	PC	Single-touch, Multitouch	✓	✓	✓	✓	✓	✓	✓	✓
75	M	Never	None	None	✓	✓	✓	✓	✓	✓	✓	✓
77	F	Monthly	None	Single-touch	✓	✓	✓	✓	✓	✓	✓	Hint
78	F	Daily	Mac	Single-touch	✓	✓	Hint	✓	Demo	Hint	✓	✓
84	F	Daily	PC	Single-touch	✓	✓	Hint	✓	Hint	✓	✓	Hint
84	M	Daily	PC	None	✓	✓	✓	✓	Demo	✓	✓	Hint
85	M	Daily	PC	Single-touch, Multitouch	✓	✓	✓	✓	✓	Hint	✓	✓
86	F	Daily	PC	Single-touch	✓	✓	Hint	✓	✓	✓	✓	✓
88	F	Daily	PC	Single-touch	✓	✓	Hint	✓	✓	✓	✓	Hint
88	M	Daily	PC	Single-touch	✓	✓	✓	✓	✓	✓	✓	✓

Table 1. Computer experience for participants and whether participants figured out each action on their own (checkmark), needed a hint about interaction (hint), or required a demonstration of the action (demo). Touch-screen experience: (single-touch) prior experience with devices such as point-of-sale systems and bank automatic teller machines and (multitouch) prior experience with devices like the iPhone or Microsoft Surface.

and social channels (e.g., commercial advertisements, watching a friend use a multitouch cell phone). Observations and data below focus on older adults except where noted.

A researcher followed a written script to guide participants through a series of tasks. The first task involved getting the participant comfortable in an adjustable office chair and situated at the table. The participant then manipulated paper information cards spread out on the table surface (at this point the display was off, see Figure 2). The goal of this first activity was to ensure that the participant was comfortable at the table while interacting with the entire surface.

After the paper-based task, each participant completed seven brief activities (each lasting about 5 minutes) on the multitouch surface. The ordering of activities was randomized between subjects. For each activity, the moderator first explained the context of activity (e.g., “Suppose the doctor took an x-ray of your hand and now wants to review it with you.”). Then she asked the participant how they would perform the task (e.g., “If you want to make this x-ray larger, how might you do that?”) and observed their behavior. Participants were given a hint if necessary (e.g., “You need to use two fingers or two hands to make the x-ray larger.”). If the participant still had trouble figuring out the action, the moderator gave them explicit instructions and demonstrated the action for them. The participant was encouraged to try the action several times. Then the participant rated on a seven-point Likert scale the level of difficulty for figuring out the action and the level of difficulty for physically performing the action. After completing all activities, we used a structured interview to examine each participant’s reaction to surface computing as well as ideas for using this technology in a medical setting. Participants performed activities individually, but if two or three participants came to the study together, we allowed them to do the structured interview as a group to encourage discussion. Two researchers were present for all sessions and took detailed notes. Each session was video recorded by two cameras, one mounted directly above the table and another positioned in the corner of the testing room.

Figure 2. Participant (age 88) getting situated at the computer and in the adjustable chair during the paper card task.

RESULTS

The majority of older adults independently figured out how to perform touch-based interaction with the surface computer (see Table 1) and found the various forms of interaction physically manageable. The idea of using surface computing to support health care interactions was also well-received by participants.

Touch-Based Interaction

After performing each task, participants rated the ease of learning and ease of performance for that particular task (see Figure 3). Some types of interaction (e.g., panning and drawing) were harder for participants to figure out than to physically perform. In contrast, reading text on the surface was

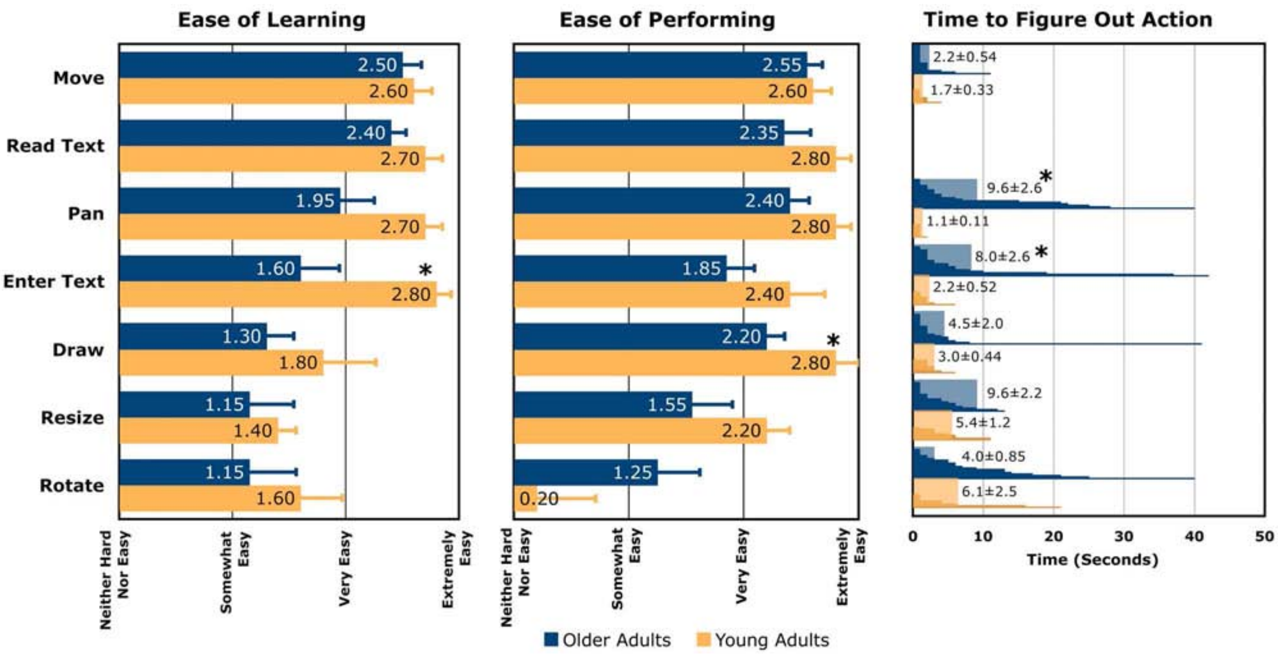


Figure 3. Self-report data for ease of learning (left) and ease of performing (center) each type of interaction. Data was collected via a seven-point Likert scale (extremely hard=-3, extremely easy=3). On average, older adults rated all interactions as "somewhat easy" or better for learning and physical performance. Graph on the right indicates individual participant data (translucent bar overlay is average) for time to figure out each task. Results were not significantly different between older and young adults except where denoted with a star (calculated with Mann-Whitney U test; learning to *enter text*, U=148.0, $p<0.017$; performing *draw*, U=150.0, $p<0.014$; time to figure out *pan*, U=158.5, $p<0.0003$; time to figure out *enter text*, U=131.0 $p<0.028$). Error bars show standard error.

rated as easy to figure out but slightly harder to perform because of issues such as the angle of the display, which is discussed further below. Figure 3 (right) illustrates the time it took each participant to figure out each action. Importantly, the average score by older adults for ease of learning and ease of performance for all tasks is "somewhat easy" or better, and the average time it took older adults to figure out each form of interaction was less than 10 seconds.

Select

While participants did not complete an activity that explicitly examined selecting, they performed the *select* gesture on a variety of objects within several activities (e.g., touching a button to enlarge text for reading, pressing a key on a virtual keyboard, choosing a paint color before drawing). Observations throughout the study indicate that selecting was straight-forward and physically manageable for participants. For smaller buttons (1" by 1"), participants typically used a single finger to select. Occasionly participants used two or three fingers grouped together to select larger buttons (2" by 2") such as the paint color in the drawing activity. Finally, the prototypes in this study are basic in terms of visual design, and subsequent designs should provide visual confirmation that a button or object was selected.

Move: arranging foods by cholesterol content

The *move* gesture was examined by asking participants to arrange images of foods along a continuum depending on how each item affects cholesterol levels. Food images were scattered throughout the top region of the display to examine issues of reaching and moving across the surface. Figuring out how to move objects around the surface was trivial for participants (mean rating=2.50, SE=0.17; mean time=2.2 sec, SE=0.54), and physically performing this gesture was equally as easy (mean rating=2.55, SE=0.14). We anticipated that some participants would have difficulty reaching objects in the far corners of the display, but this was not an issue as their position at the table enabled full range of motion across the surface (we elaborate the importance of this point in the discussion below). Most often participants used one finger for this action, but occasionally people used two fingers or a whole hand to move an object across the display. A couple participants experienced hand tremors while dragging, but these participants were still able to successfully move objects across the display. One complication participants with hand tremors experienced is that an additional finger (the thumb or little finger) would occasionally touch the surface and make the object jump around under their hand.

Resize: adjusting the size of an x-ray image

Participants were asked to *resize* an x-ray image (perform *enlarge* and *shrink* gestures). Figuring out how to resize the image was not straight-forward for many older adults (mean rating=1.15, SE=0.39; mean time=9.6 sec, SE=2.2). Only eight participants used two fingers or hands to enlarge the image on their first attempt. Seven participants first tried to enlarge the image by tapping on it, and eight (some of whom also tapped) tried enlarging the image by dragging one corner of the image outward with a single finger (see Figure 4, left). One lady (age 84) asked, "I don't see any buttons. Just tap on it?" Another woman (age 70) said, "I'm expecting this to work because on my computer you can pull out from a corner to make the window larger." Because this particular task focuses on resizing, not dragging, the image remained in the same position when a single finger moved across it. An implementation that combines moving and dragging would likely help participants realize that dragging with a single finger moves the image instead of resizing it. At the beginning of the study, participants were told that the computer is a touch-screen and that some activities might require more than one finger or hand; yet some participants were hesitant to involve a second hand in this task. Six participants needed a hint that this activity involved more than one finger or hand. When participants did use two hands to resize the image, they tended to place their fingers on the edges of the image and move outward horizontally. Most people did this with two index fingers, but some people used several fingers or their whole hands to "spread out" the image. Some participants suggested adding a visual cue (e.g., handles on the image edges) to help people understand that a two-finger action is required. Once participants figured out how to enlarge the image (move fingers apart), it was trivial for them to determine how to shrink the image (move fingers together).

Figure 4. Many participants tried to enlarge the image by touching on a corner with a single finger and moving outward (left) but some immediately touched with two fingers (right).

Rotate: turning a medical graph toward oneself

To examine a *rotate* gesture, we presented users with a graph of blood pressure levels over a period of time, but the image was initially oriented toward the moderator. We asked participants to turn the graph/chart toward themselves so they could view it. Rotation was possible by touching on a corner of the image with a single finger and moving in a circular direction, and nine participants immediately touched a corner with a single finger and began rotating the image. One participant first touched an edge and attempted rotate. The other ten participants first used their whole hand or two hands to rotate the image before realizing that a single finger on the corner was the desired action. One lady (age 74) said, "My instinct was to turn it like a regular paper, physically with two hands." With two finger rotation, participants expected one finger to serve as an anchor point while the other finger rotated the object around. Rotate tied with resize as the most difficult to learn (mean rating=1.15, SE=0.41), and rotate was rated as the most difficult to perform (mean rating=1.25, SE=0.37). Regardless of how participants started rotating, they were all able to independently figure out how to rotate the image. However, almost everyone had problems stopping the image in the exact orientation they wanted. For example, one man (age 84) summarized this common problem, "More damping would be helpful. This is a little jumpy. I tend to overshoot." Overall, rotating by touching on the corner of an image was not intuitive for everyone, and the implementation requires smoothing and slowing to enhance usability with older adults.

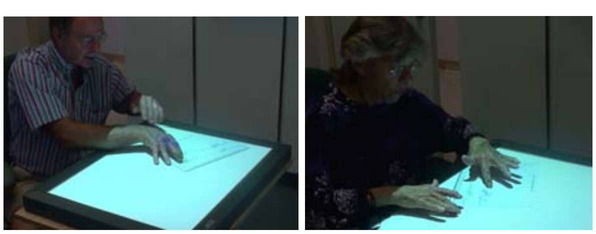


Figure 5. Some participants had difficulty rotating because they used their whole hand (left) or two fingers (right) to perform this action.

Pan: viewing medication types and dosages

Participants performed a right and left *pan* gesture to look through various brand packaging and pill shapes for ten over-the-counter medications. This activity started with four brands of medicine on the display, two of which were partially off the screen to provide a cue that content extended beyond the current view (see Figure 6). Participants could use any number of fingers to pan. On average participants rated the ease of learning for panning as "very easy" (mean rating=1.95, SE=0.30), but ironically participants took the longest time to figure out the action (mean time=9.6 sec, SE=2.6; tied with resize). Physically performing a panning gesture was not a problem for participants (mean rating=2.40, SE=0.17). Several participants who quickly understood this form of interaction referenced their experience with traditional window-like scrollbars. For example, one lady (age 70) commented, "This is easy for someone who has computer experience because we scroll all the time." As another woman (age 77) contemplated the task, she said "On other computers you can scroll up or down," and then successfully performed the horizontal pan gesture. Five participants needed a hint or explicit instructions to understand the panning action. Some participants who had difficulty figuring out the panning metaphor said they wanted a clear indicator that off-screen content exists (e.g., arrows).

Draw: indicating pain points on a body diagram

To examine whether participants were able to *draw* with the tip of their finger on the surface, we asked participants to se-

Figure 6. Participant (age 85) uses his whole hand to pan through various medications.

lect a paint color and draw on a human body diagram to indicate areas where pain has improved (green), stayed the same (yellow), or gotten worse (red). While all participants were immediately successful at drawing with their finger, seven people touched a paint color and attempted to drag the colored circle up to the figure (hence the lower rating for ease of learning: mean rating=1.30, SE=0.24). It was not clear to them that they were able to select a color, release their finger, and then draw with that color on the diagram. One reason for this is likely the implementation of our prototype, as it was minimalistic and did not provide users with feedback about which color was selected. The point of this activity was to examine the feasibility of drawing with a finger tip, and all participants understood the concept of drawing with their finger and were able to perform this action with ease (mean rating=2.20, SE=0.16). After performing this task, a man (age 64) said, "I would say it's extremely easy. It's like finger painting."

Read Text: reviewing side effects of a medication

Participants viewed a text description of the side effects of generic aspirin and were asked to adjust the text (presented in a sans-serif font) to a comfortable size for reading. This activity had a "larger" and "smaller" button at the bottom of the display that participants used to increase and reduce the text size. Average preferred text size for reading text close to the user is 1/4" (measured by capital letter height) and for reading text far away is 5/16". Figuring out how to change the text size was not problematic for participants (mean rating=2.40, SE=0.13); however, some participants said the horizontal orientation of the display made it difficult to read text (in agreement with [16]). Nine of 20 participants said that they wanted the display to tilt slightly so that reading text would be easier. Participants liked the idea of dynamically adjusting the text size, and future designs should consider this option. About half of participants brought two pair of glasses to the study. One woman (age 70) who brought bifocals and magnifying glasses read text on the display with each pair of glasses, and stated, "it works fine with bifocals." Other participants wearing bifocals echoed this sentiment.

Enter Text: signing in at the medical facility

We examined participant reactions to and ability to use a virtual keyboard through an activity that simulated a sign-in terminal in the reception area of a medical center. The QWERTY keyboard was designed larger than necessary to ensure that participants could accurately touch each key. Entering text on the virtual keyboard was straight-forward for all but four participants. In fact, many participants began entering their name before the task was explained to them. Participants who had difficulty figuring out this activity looked for a stylus to write their name. One man (age 85) said, "I'd look for a wand for signing in." Over half of participants recommended that the keyboard be made slightly smaller so that touch typing is possible and to increase the contrast of the letters on each key. For example, one lady (age 88) looked at the display and said, "Ok, this is a typewriter but the spacing is not right." After typing her name, she explained, "I would say that's not easy because I'm used to touch typing. The spacing is different. If it were like a keyboard it would be very easy." Typing errors most often occurred when people used their fingernail, instead of their fingertip, to touch the keyboard (this surface is capitative and requires contact with a fingertip). Finally, several participants could not find the space bar, so labeling it as such would be helpful. Overall, the virtual keyboard was suitable for brief text entry, and once participants figured out how to use the keyboard, all said that it was fine for this task compared to a traditional keyboard.

Feedback on Health Care Scenarios

The goal of situating this laboratory-based study within the context of health care was to explore a variety of application ideas with older adults. It is important to note that participants' success with a particular form of interaction did not appear to interfere with their ability to understand the proposed scenario, as the rotate gesture was most challenging yet the application idea was rated second highest and all ideas received an average score of "somewhat useful" or better (see Figure 7). The top three ideas include reading through medication side effect information with your doctor, viewing a graph/chart of your medical history (e.g., blood pressure), and drawing on a diagram of a human figure to discuss pain management with your doctor.

Viewing a shared description of the side effects of a medication received high ratings from participants. They liked the idea of reviewing text-based information with a doctor to point out areas of concern. Also, participants stated that they liked the adjustable nature of the text in this activity. The medical chart viewer was well-received as participants wanted to have a shared visual representation of their medical history. Regarding drawing, participants thought the application would be useful for clarifying to the doctor exactly where pain is located. One lady (age 84) said, "...it specifies exactly where the pain is and that's a lot easier than saying 'doctor, I feel it over here or over here'... it's very graphic, a good idea." In general, participants wanted to have visuals

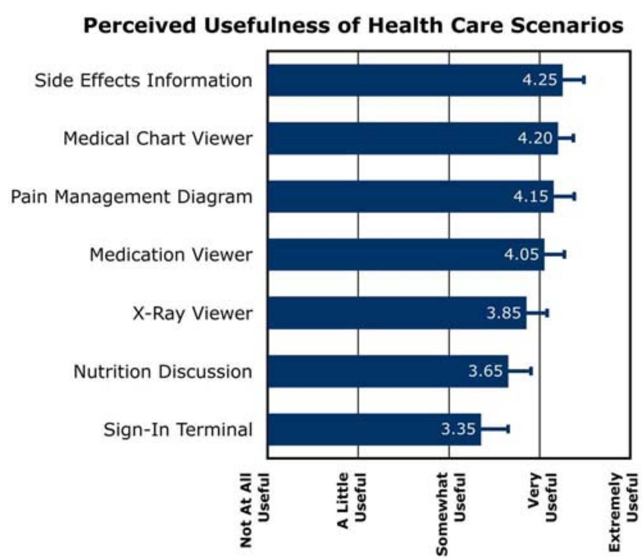


Figure 7. Older adult ratings for perceived usefulness of each health care scenario.

to augment conversation with the doctor such as medicine labels, pill sizes and shapes, x-rays, and food choices. One man (age 60) said, "I like the visuals... the pictures help... if you have the pictures there, [the doctor can] say 'ok, now I know what you want."'

Attitude Toward Surface Computing

An important aspect of surface computing for the older adult population is how the technology affects people's perceptions of their ability to interact with a computer. To assess this, at the beginning of the study participants rated their agreement with six statements pertaining to computers in general. After using the surface computer for about 30 minutes, participants rated their agreement with the same six statements pertaining to this particular experience. Figure 8 illustrates the results. For older adults, the difference between positive statements about general computing and the surface computer was not statistically different. However, older adults tended to disagree more strongly with negative statements about their experience with surface computing (all three are statistically significant with the Wilcoxon matched-pairs signed-ranks test: $W=9$, $p<0.004$; $W=16.5$, $p<0.003$; $W=11$, $p<0.007$, respectively). One man (age 60) who rarely uses a computer explained, "I'm not intimidated by this because I can use my hands and move things around... I can play with it and figure it out." In summary, the surface computer appears to be less intimidating, less frustrating, and less overwhelming than participants' usual experience with computers. Interestingly, young adults' attitudes toward general computers compared to the surface computer were not statistically different for positive or negative statements.

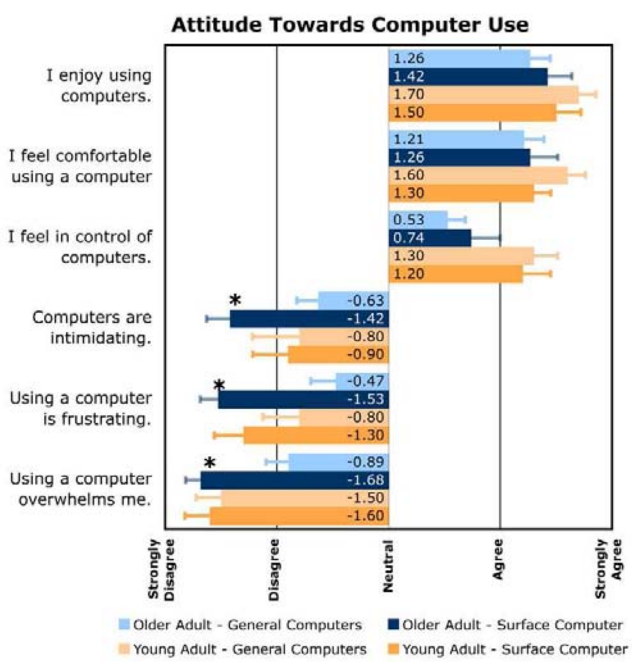


Figure 8. Agreement ratings for statements about attitude toward computer use. For older adults, the difference between general computers and the surface computer for negative statements is significant. No significant difference in attitude was found for young adults.

Generational Differences

Comparing interaction between older and younger adults reveals several important similarities and differences. First, many younger participants had the same expectations for interaction as the older participants (e.g., resizing an image by tapping or moving outward with a single finger, rotating with two fingers). However, young adults quickly tried various ways of interacting until they figured out the desired gesture. Only one young user said they could not figure out an action (resize) and requested a hint, whereas older users were more likely to wait for a hint rather than exploring until they figured out the action. There was also a certain reticence or hesitancy in interaction for older adults. This can be observed in the way they touched the display lightly with a single finger tip, as if to minimize impact to the system. Another difference is that even though young adults in this study had minimal exposure to a multitouch device, they had high expectations for the quality of interaction (i.e., low tolerance for an image not rotating smoothly). In fact, younger users rated the ease of performing rotation lower than the older adults (see Figure 3). Finally, younger users bring to bear computer experience that may work against them with the simplistic interaction presented in this study. For example, four young users had initial difficulty with the text entry activity because they wanted to ensure that the cursor was in the correct spot before entering their name. There was no cursor to manage in this scenario, which confused some younger users but went unnoticed by all older users.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Interaction Design

While touch-based interactions were relatively easy for participants to figure out and perform, we discuss several ways in which interaction can be improved to better accommodate the needs of older adults.

Touch interaction is manageable and preferred. Overall, we were surprised by how well older adults performed each type of interaction. Participants enjoyed multitouch interaction and called it "fun" and "engaging." We suspected that certain actions, specifically panning, might be tiresome for participants, yet all but one person said they prefer to use their hand to pan across the surface compared to having buttons to scroll through options. We encouraged participants to perform each gesture multiple times, especially actions that have a high level of arm movement such as the pan and move gestures. While our data do not assess whether these gestures will fatigue users over time, not a single older adult mentioned that an action might become tiresome. Nevertheless, future work in which such a system is placed in a real world setting for extended use should address these aspects of interaction.

Provide cues for interaction. For many participants, the interaction with virtual objects on the multitouch surface was intuitive. However, providing more explicit cues for interaction would help facilitate initial learning and perhaps subsequent use of the technology. For example, many participants did not immediately know whether an object was selectable, dragable, resizable, and/or rotatable. Indicating this functionality visually would aid usability. Participants also wanted to know when they needed to use more than one finger (or more than one hand) for a particular action. While enlarging and shrinking an image was trivial once users figured out the action, the two finger (or two-handed) resize gesture caused initial confusion for over half of users. One way to indicate a multitouch gesture is by adding visual touch points (e.g., grips or handles) to the side of a resizable image.

Slow down interaction. The rate at which virtual objects adjust based on subtle hand movements, particularly during resizing and rotating actions, needs to be slowed down. Participants appeared to be more concerned with accuracy in manipulating objects than the speed of interaction. This was observed in the way many participants spent time carefully adjusting the rotatable chart so that it was exactly horizontal and faced them perfectly. Subsequent multitouch systems for older adults should include easing or damping in interaction. Objects that snap in place (perhaps at regular angles for the rotate gesture) would help older users avoid the challenges of fine motor movement required to align an object.

Avoid fine motor input. The ability for the interface to allow whole-handed and multifinger input is critical. This is particularly important for individuals with hand tremors or arthitis. In fact, one lady (age 70) with arthritis in her hands said the technology "would be very good for people with arthritis or who have hands that don't work right." The drawing activity required a single finger for interaction, and this was challenging for some participants who accidentally touched the display with other fingers. Dragging allowed input through any number of fingers, but the image jumped around when other fingers unintentionally touched the display background. For this example, the gesture recognizer could mitigate the impact of additional unwanted fingers contacting the display during an action. A fingertip is a blunt and imprecise input device, and the effects of imprecision with touch input are exasperated for older adults with limited dexterity. Three people in this study (all men in their 80s) suggested that we enable interaction through a stylus. One man (age 84) who experienced hand tremors said, "I would be more comfortable if I had a pen in my hand... I'd have more control."

Form Factor and Industrial Design

The size, height, and adjustability of the surface computer are important to consider in the design of subsequent systems for older adults.

Positioning at the surface is critical. Our study examined a 75 cm by 60 cm horizontal surface computer. Reaching the far corners of this surface was not problematic for any participant. No participant complained about back or neck pain during the 30 minute session of use. Furthermore, observations of participants' posture in the chair and movement at the table did not indicate issues of discomfort. A primary reason for this is the setup of the table and chair. The thin form factor of the DiamondTouch table on a pedestal stand allowed people to position their legs under the table. Participants were able to adjust the chair height to a comfortable position for interacting throughout the surface. The lack of leg room and low positioning of other tabletop models (e.g., Microsoft Surface) may present problems for older users.

Consider a tilted or adjustable display. Almost half of participants (9 total) suggested that the surface should be at an angle to improve usability. "This is weird. Canted would be so much easier... My vision is not wonderful. If it were raised at a 30 degree angle... it would be much easier for me," commented one lady (age 78). Another lady (age 84) explained, "I think it should be at an angle so the doctor can see it better and also the patient can see it better...the patient would have to sit along side the doctor." "It's funny that it's flat. I would expect it to be on an angle...almost like an easel," said another woman (age 67). While participants were keen on tilting the surface, the tradeoffs in terms of usability and cooperative work should be considered carefully (see [16, 17]).

Display size may be intimidating. Many participants liked the large display for sharing information with medical professionals, but a few participants mentioned that the size of the display may be intimidating in a doctor's office. "I'm not sure that the screen has to be quite so large... The patient might feel intimidated by the size of the screen," commented one woman (age 84). Some people said that a smaller display, about half the size of the current surface computer, would be sufficient and less intimidating. The most appropriate size for a display needs further exploration, as smaller multitouch surfaces are less expensive and increasingly available (e.g., HP TouchSmart).

Exploring the Domain of Health Care

Overall, participants talked enthusiastically about using a surface computer in a medical setting and gave positive feedback on the idea. Participants articulated, from a patient's perspective, how the computer would fit into the workflow of a medical visit. Several people referenced their current experience with digital patient records. One woman (age 65) recounted an experience where there were several mistakes on her record, but she did not notice because the notes were on the doctor's small computer display. "You go to [a medical provider] and the doctor is over here looking at the computer screen... we'd have to get behind the doctor to look at the computer screen," she said. Her friend (age 67) replied, "You have to be practically on top of them and get in his space." With respect to the shared nature of the surface computer, the first woman explained, "The opportunity to catch mistakes would be doubled when you have two people." Having a shared view of one's medical records was perceived as a strong benefit of the surface computer.

Participants also expressed concern about using a surface computer in a medical context. Several people mentioned that patients have a right to view their medical information, but at the same time, not everything should be modifiable. Shared display systems for health care need mechanisms to control access to certain information. One woman (age 67) was concerned that patients might "reach in and mess things up." She said, "They'd almost have to lock it." Another lady (age 65) commented on her willingness to interact with the shared computer surface, "It's owned by the doctor...We'd at least ask permission, or we'd have to be invited [to use it]." Technologies such as the DiamondTouch that can detect individual users would be helpful for controlling access to various parts of the shared display in a medical setting.

CONCLUSION AND NEXT STEPS

This paper reports results from an exploratory study involving older adults using a multitouch surface computer. Older adults were able to perform all actions on the surface, but several aspects of software and hardware design need to be reconsidered to improve usability for this population. The present study provides insights about older users' conceptual expectations and physical demands of various gestures. Future work should examine the integration of individual gestures into a single application (i.e., where users can resize, rotate, draw on a single image). While this study examined touch input directly to the surface, light-weight physical controls (e.g., SLAP Widgets [20]) stand to benefit the unique needs of older users. For example, individuals with hand tremors might find physical controls easier to manage than touch input. Lastly, an evaluation of surface technology for health care support must be conducted in an authentic setting. People act differently under emotional stress due to an illness or may be more limited when they are sick or hurt. Other factors such as surface hygiene will be important when the device is installed in a medical facility. Several participants were concerned that doctors are already limited by time, and the surface computer might slow down the medical interview process. Ease of learning for novice users is crucial if the technology is placed in a time-critical setting such as a medical facility. Our ongoing work involves installing a surface computer in an authentic medical setting to assess these issues.

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