# Personal Digital Assistants (PDAs) as Medication Reminding Tools: Exploring Age Differences in Usability

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*C.B. Mayhorn, V.R. Lanzolla, M.S. Wogalter, A.M. Watson, Personal Digital Assistants (PDAs) as Medication Reminding Tools: Exploring Age Differences in Usability. Gerontechnology 2005; 4(3):128-140.* **Purpose** Medication adherence by older adults can be important in returning to and maintaining health. New technologies may be helpful in facilitating adherence. This article examines age differences in usability for one device: the personal digital assistant (PDA). **Design and Method** In the experiment reported here, 25 older and 26 younger adults were asked to learn to use medication adherence software supported by a PDA. In addition to completing a battery of cognitive tests and a survey designed to assess perceived PDA usability, each participant's PDA skill acquisition was assessed over time (i.e., during training, immediately following training, and after a delay). **Results** Consistent with previous research, older adults required longer to learn to use the PDA and committed more errors compared to younger adults. Over time, age differences in PDA performance were reduced suggesting that older adults might benefit from PDAs as prospective memory aids during medication adherence. **Implications** Potential directions for PDA training curricula, hardware design, and future research are discussed.

**Keywords: aging, technology, usability, medication adherence, cognitive support**

Older adults, aged 60+, are becoming increasingly aware of the benefits of using computerized technology to enhance their daily lives[1,2]. While a common misconception is that older adults are averse to change and unwilling to use new technology such as computers or the internet, recent assessments of older adults generally show that they possess positive attitudes and express a willingness to learn to use these devices[3,4]. Although these results are encouraging because they suggest that older adults are adopting desktop computing technology, the findings may not be applicable to newer technology that is becoming available to the public. Current trends in device design are transitioning from traditional desktop workstations to mobile, handheld devices such as personal digital assistants (PDAs) and cellular telephones[5]. It is unclear whether these newer, miniaturized devices would be of benefit to older adults given well-documented perceptual, motor, and cognitive declines[6,7].

Ownership of handheld devices is becoming increasingly ubiquitous among users of all age groups[8], yet the usability needs of older adults have received very little attention. Consider the recent trend in combining the basic functionality of cellular telephones with the advanced computing attributes of PDAs. PDAs are handheld computers that possess multiple features such as address books, to-do-lists, and calendars that can serve a mnemonic function. Because PDAs are becoming increasingly affordable and allow portable access to information, the likelihood that older adults can benefit from adopting the use of these new devices is promising. For instance, PDAs might reduce the risk of injury to older adults by issuing warnings that call attention to themselves and deliver safety information when and where it is needed[9]. For these reasons, advances in wireless technology have been hailed as one approach to meeting the healthcare needs of older adults in the new millennium[10].

One area within the realm of healthcare that is particularly problematic for older adults is medication adherence which has been defined as a patient using doctor prescribed medication as directed[11]. Correct adherence entails taking the medication at the correct times, at the indicated dosage, and following any special instructions as directed on the label (which can be quite complicated). Due to the onset of chronic conditions such as osteoarthritis and hypertension, the average older adult uses 4-5 prescription medications concurrently and it is not uncommon for some older adults to use as many as 10 or more[12,13].

The consequences of improper medication usage can be severe, and are in fact staggering. In terms of human suffering, one recent study indicated that more than 2.2 million people are hospitalized each year for serious adverse drug reactions and that approximately 106,000 people lose their lives due to medication error each year[14]. The annual economic cost of medication-related errors in the United States alone has been estimated at nearly US$85 million[15]. While a number of variables such as illness representation, patient-doctor communication, medication labeling, and patient motivation have been explored to explain the causes of medication-related error, the cognitive aspects of the medication adherence task have been the focus of numerous studies[16]. Cognitive factors such as complexity of schedule, number of prescribing physicians, and number of medications all tend to correlate with non-adherence[13]. An estimated 71% of non-adherence is under use of the medication, in large part due to forgetfulness[17].

Remembering to take medication requires the use of prospective memory which can be defined as remembering to perform an action some time in the future[13]. One way to assist in the accomplishment of prospective memory tasks is to provide cognitive support. Here, cognitive support refers to the assistive aspects of technology that enhance the mental capabilities (and avoid the limitations) of users. For instance, active supports such as alarm clocks call attention to themselves and have been shown to be effective in facilitating prospective memory[18].

Given these findings, PDAs have the potential to benefit individuals of all ages who have complicated medication schedules. These devices can relieve the individual of having to rely on memory to retain details of his or her schedule and other pertinent medication-related information (e.g., take with milk, after dinner) as well as serving as a source of active support by activating an alarm to announce a scheduled dosage. Arguably, a number of existing external memory aids such as voicemail reminding systems, vibrating wristwatches, and special pill dispensers are commercially available and likely to improve medication adherence[11,13]. However, several limitations of these devices may make them less effective at medication reminding than PDAs. For instance, the voice-mail reminding system will only be effective if people remain in close proximity to a telephone and may not be cost effective in terms of setup. Vibrating wristwatches may provide an active reminder alarm that something has to be done at a particular time but pertinent medication-related information (i.e., what medication must be taken; proper dosage, etc.) is not available. Likewise, special pill dispensers may provide the needed medication-related information but lack the active alarm system. Thus, PDAs might be more successful than these other devices because they combine the features of affordability (as the devices become more widely disseminated), portability, access to medication-related information, and active alarm systems.

Obviously the potential financial and health benefits of PDA usage by older adults are great, yet the realization of this potential is dependent on their usability with respect to this special population. For instance, current PDAs utilize small LCD displays that have less ability to display sharp contrasts than larger monitors do. Screen size, and therefore font, icon, and control size is limited making for greater difficulty in reading and manipulating the interface. While it has been reported that older adults have difficulty with text entry on PDAs[19], other aspects including the overall usability of these devices with older adult samples have not been investigated. Although older adults have apparently adopted traditional desktop computers, this study will focus on how well they can learn to use handheld devices. Thus, the purpose of the present study was to compare the performance of younger and older adults on a PDA-based medication scheduling task on three separate occasions. Task performance data such as time to complete the tasks and error production were supplemented with subjective measures of perceived usability. The goal was to determine whether age differences in performance influenced the likelihood to use these devices in the future.

## Method

### Design and Participants

A 2 (age: younger vs. old) X 3 (time of assessment: practice, immediate assessment, delayed assessment) mixed factorial design was used. Age was the between subjects grouping variable and time of assessment was a within subject variable. The dependent variables were time on task and number of errors made. Each dependent variable had three measures such that there was one for each phase of the training: practice, immediate assessment, and delayed assessment.

Twenty-six younger (mean age of 18.6 years, SD = 1.36, range = 18-23) and 25 older (mean age of 67.3 years, SD = 5.24, range = 60-76) adults participated. The younger participants were recruited from an undergraduate research participant pool and received partial course credit. The older participants were community-dwelling adults who were recruited from computer education classes at a local senior center and paid for their participation. Only participants with some computer experience and no PDA experience were allowed to participate. This was done to ensure at least minimal computer literacy and yet not introduce the confounding variable of prior PDA experience. Testing was divided into two experimental sessions such that Day 1 was comprised of group-administered demographics and abilities tests whereas Day 2 was composed of individual PDA instruction and testing.

Demographic and abilities information was collected for the purpose of describing the two samples. When participants evaluated their general health on a scale of 1 ('Poor') to 5 ('Excellent'), mean responses from both age groups approximated 4 ('Very Good') such that no age-related differences in perceived health emerged, $p = .36$. To describe the level of education that they had completed, participants used a scale of 1 ('Less than high school') to 7 ('MD, JD, PhD, other advanced degree'). The mean response for the younger adults approximated 3 ('Some college') while that of the older adults was significantly higher and approximated 4 ('Bachelor's degree'); $t(49) = 4.33$, $p < .001$. As illustrated in Table 1, the technology experience and usage questionnaire (TCEQ)[20] was used to assess participants' experience with and usage of computers and the world wide web. Older adults reported significantly less experience with computers and the world wide web than younger adults; $t(49) = 2.32$, $p < .05$, $t(49) = 2.89$, $p < .01$, respectively. Older adults also reported using the world wide web less than younger adults, $t(49) = 3.94$, $p < .001$. Thus, the samples were generally healthy, but varied significantly in terms of their education and reported usage/experience with desktop computer technology.

A battery of cognitive tests was administered to all participants and included measures of vocabulary[21], reading comprehension[22], spatial abilities[23], working memory[24], and perceptual speed[25]. Mean performance for each age group is listed in Table 1. Older participants performed significantly better than younger participants on the vocabulary test, $t(49) = 3.09$, $p < .01$. However, younger adults performed significantly better than the older adults on the measures of working memory, reading comprehension, spatial ability, and perceptual speed; $t(49) = 2.20$, $p < .05$, $t(49) = 3.12$, $p < .01$, $t(49) = 6.44$, $p < .001$, $t(49) = 8.46$, $p < .001$, respectively. Collectively, these patterns of results indicated that the samples were representative of their respective populations.

**Stimulus Materials**

Participants were asked to enter information into a commercially available medication tracking software package on a PDA. The PDAs were the Palm Zire, utilizing the Palm operating system, with a 160x160 pixel monochrome display. The On-Time Rx software was used because it was advertised by the manufacturer as 'intuitive and easy to use' [26].

*Table 1. Group Means (Standard Deviations in parentheses) for Technology Experience and Cognitive Measures; [a] Total Score from the Shipley Vocabulary Test[21]; [b] Number of trials correctly recalled on the Alphabet Span Test[24]; [c] Total Score from the Nelson-Denney Reading Comprehension Test[22]; [d] Number of trials correctly completed on the Paper Folding Test[23]; [e] Total Score on the Digit Symbol Substitution Test[25]*

| Variable | Younger (n = 26) | Older (n = 25) |
|---|---|---|
| TCEQ - Computer Experience | 35.5 (3.4) | 30.1 (11.5) |
| TCEQ-Web Use | 13.4 (1.4) | 9.5 (4.8) |
| TCEQ-Web Experience | 20.2 (6.2) | 13.9 (8.9) |
| Vocabulary[a] | 28.8 (4.5) | 32.7 (4.7) |
| Working Memory[b] | 36.0 (12.9) | 29.1 (9.2) |
| Reading Comprehension[c] | 31.9 (5.5) | 25.2 (9.3) |
| Spatial Ability[d] | 13.8 (3.0) | 7.8 (3.6) |
| Perceptual Speed[e] | 70.3 (8.8) | 49.5 (8.8) |

The on-screen keyboard was used as it is On-Time Rx's default method of data entry.

Based on pilot testing with older adults, the manual provided by the On-Time Rx software manufacturer was deemed inadequate for use by participants. To clarify, the commercially available manual lacked procedural detail, provided only abbreviated text-based instructions for software usage, and did not provide step-by-step illustrations to guide performance. To address these issues, a task analysis was conducted. Based on the results of the task analysis, an illustrated manual (available from the first author upon request) was constructed to teach the participants to use the On-Time Rx software. The manual illustrated every step necessary to enter a medication's information. Participants learned to use the PDA and software by following the instructions in the manual to perform a medication entry task during the practice phase of training. This active learning method, which pairs instruction with hands-on action, has been shown to be more effective than simply reading instructions for older adults[27].

Because medication entry was accomplished through the use of the PDA stylus, a stylus tester program was developed by the experimenters to ensure a minimum level of competency with the stylus and the tap-screen interface. The program randomly placed a box on the screen and the participants had to tap the interior of the box within two seconds. This was repeated 20 times. An 85% success rate was considered minimum competency. Participants were given three attempts to reach minimum competency. All participants were able to attain the minimal level of competency.

**Procedure**

On Day 1 of testing, groups of up to 10 participants completed a demographic questionnaire and the cognitive battery during an experimental session that lasted for approximately two hours. On Day 2 (non-consecutive), participants were individually tested for near-normal vision (defined as 20/40 corrected), and the ability to accurately use a stylus. They were then tested for their ability to learn the procedures necessary for medication entry on the PDA program.

Participants were given the instruction manual and asked to follow the manual step by step to practice entering a medication (practice assessment). They were then asked to enter a second medication (initial assessment). The Everyday Cognition Battery Reasoning Questionnaire[28], was then given as a distracter task, for a period of 25-30 minutes to reduce the likelihood of rehearsal of the PDA procedure during the intervening period. Having completed the distracter task, participants were asked to enter a third medication (delayed assessment). As instruction use is not mandatory in real life, use of the instruction manual was optional for the initial and delayed assessments. This was done to make the task as naturalistic as possible. An experimenter was present at all times, though the participants were encouraged to perform as much of the work on their own as possible without asking the experimenter for assistance.

To enter a medication, participants entered the name of the medication, the dosage, number of doses per day and their administration times, frequency (daily, weekly, monthly), and any special administration instructions (e.g., after meals, at bedtime). They were then to review the daily schedule screen to verify the accuracy of their work. For each trial, the experimenter watched and recorded time on task and error production. Errors were classified as either cognitive or motor control. Some examples of cognitive errors are forgetting to include a step (e.g. not setting the schedule to repeat), adding a step (e.g. changing the frequency when the default is correct), repeating a step, or evidencing search errors (e.g., repeatedly returning to the same pages in the menu). Motor control errors occurred when the participant missed a target, moved the stylus off the target during selection, or failed to press hard enough to activate the target.

To supplement the performance data derived from the experimental session, participants completed a survey designed to assess the perceived usability of the PDA. The survey included six usability agreement ratings and three open-ended questions regarding PDA feature utility. To assess the perceived usability of the PDA hardware, participants were asked to rate their agreement on statements concerning: (i) overall satisfaction, (ii) simplicity of operation, (iii) ease of medication information entry, (iv) ease of learning, (v) error recovery, and (vi) likelihood of future use. The specific statements were:

1) Overall, I am satisfied with how easy it is to use the PDA.
2) The PDA was simple to use.
3) I could effectively enter medication information into the PDA.
4) It was easy to learn to use the PDA.
5) Whenever I made a mistake using the PDA, I could recover easily and quickly.
6) I am likely to use a PDA in the future.

Each statement was accompanied by a Likert-type scale with whole-number anchors ranging from one to seven. On the scale, 1 was labelled ‘strongly disagree’, 4 was labelled ‘neutral’, and 7 was labelled ‘strongly agree’.

Next, participants were asked to complete the following open-ended questions regarding utility judgments of the ‘best’, ‘worst’, and ‘future’ PDA features:

1) Describe one thing you consider best about this PDA.
2) Describe one thing you consider worst about this PDA.
3) Describe something new you would most wish to see in a future version of a PDA.

After participants completed the questionnaire, they were paid for their time, debriefed, and excused.

## Results

To assess age differences in PDA performance, a series of analyses were conducted. First, task performance in terms of time on task and error production was analyzed. Second, zero-order correlations were used to determine the relationship between task performance and specific cognitive abilities during the delayed assessment. Third, based on the correlational analyses, a series of hierarchical regressions were conducted to determine which predictor variables were most important in producing PDA performance during the delayed assessment. Fourth, the results of the perceived usability survey were examined to determine whether the age groups held differing opinions on PDA usability. Alpha levels of all analyses were set to .05.

### Analyses of PDA Task Performance

Three 2 (Age) X 3 (Time of Assessment) repeated measures analyses of variance were performed on the dependent variables of (1) time on task, (2) number of cognitive errors, and (3) number of motor control errors. Analysis of time on task revealed a main effect of age, $F(1, 49) = 56.82$, $p < .001$. Also significant were the main effect of time of assessment, $F(2, 98) = 141.5$, $p < .001$, and the interaction of age and time of assessment, $F(2, 98) = 12.97$, $p < .001$. These results illustrate that the younger adults were faster at completing the medication entry task than older adults across trials *(Table 2)*. Tukey's HSD test indicated that participants of both age groups took more time in the practice assessment (M = 465.91 s), than in initial (M = 284.53 s) which in turn was greater than the amount of time spent on the delayed assessment (M = 165.91 s).

The presence of the interaction showed that the generalized decrease in time was not as consistent for the younger adults as for the older adults. This pattern of means is likely due to a floor effect. The younger adults seemed to reach a point of diminishing returns on practice, while the older adults continued to improve. It should be noted that each age group made significant improvement across assessments; however, the older adults failed to obtain the same level of proficiency as the younger adults.

Analysis of the cognitive errors showed a main effect of age, $F(1, 49) = 19.75$, $p < .001$, and time of assessment, $F(2, 98) = 54.61$, $p < .001$, yet the interaction of age and time of assessment failed to reach significance, $F(2, 98) = 2.55$, $p > .05$. The younger adults made fewer cognitive errors across trials *(Table 2)*. Each age group displayed a similar pattern of performance, in that there were more errors made in the initial assessment than in practice or delayed assessment. This finding is consistent with the ecologically valid nature of the task because use of the instructions was mandatory in practice, but optional for the other trials.

Analysis of motor control errors showed a main effect of age, $F(1, 49) = 13.06$, $p = .001$. There was also a main effect of time of assessment, $F(2,98) = 3.16$, $p = .05$; but no interaction of age and time of assessment, $F(2,98) = 1.66$, $p > .05$. The older group had a much larger variance, but the means of the last two assessments are quite similar. Both age groups' motor control errors declined across trials (Table 2).

**Correlation Analyses**

A series of zero-order correlations were performed on demographic variables such as age and previous computing experience, cognitive measures from the abilities tests, and the dependent variables (i.e., time on task, cognitive errors and motor-control errors) during the delayed assessment. The focus on the delayed assessment reflects an effort to determine the relationship between the various cognitive factors that might influence PDA performance after learning has occurred.

The results illustrated in Table 3 suggested that there was a complex relation-

*Table 2. Group Means (M) and Standard Deviations (SD) for Time on Task, Cognitive and Motor Errors*

| Time of Assessment | Group | Time on Task in seconds | | Cognitive Errors | | Motor Errors | |
|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD |
| Practice | Younger | 308 | 63 | 0.92 | 1.3 | 1.27 | 1.34 |
| | Old | 623 | 216 | 4.52 | 4.39 | 4.04 | 3.88 |
| Initial | Younger | 152 | 54 | 3.31 | 2.35 | 1.12 | 1.37 |
| | Old | 416 | 191 | 5.76 | 3.62 | 3.38 | 3.50 |
| Delayed | Younger | 97 | 15 | 1.92 | 1.16 | 1.04 | 2.4 |
| | Old | 234 | 106 | 3.60 | 2.00 | 2.64 | 2.83 |

ship between demographic variables, cognitive function, and PDA performance. Consistent with previous analyses, age was correlated with all of the cognitive and demographic variables. All of the demographic and cognitive measures were significantly correlated with time on task whereas only cognitive measures correlated with cognitive error production. Interestingly, self-reported web-use (r = -.3) was correlated with the number of motor control errors observed, however, none of the cognitive measures were related.

**Regression Analyses**

A series of hierarchical regressions were performed on each of the outcome measures of time on task and cognitive errors during the delayed assessment. Because the standard predictors of computer performance have not yet been assessed in the PDA environment, the number of predictor variables and their ordering in each hierarchical regression were guided by the correlational analyses. As none of the cognitive or experience variables strongly correlated with the occurrence of motor control errors during the delayed assessment, the occurrence of motor control errors will not be discussed further. To control for chronological age, this variable was entered first in all regressions followed by the remaining cognitive and experience variables that correlated with each criterion variable (i.e., time on task and cognitive errors).

*Time on task*

In the delayed assessment; age, web use, computer experience, perceptual speed, and web experience all added significantly to the model, accounting for almost 85% of the variance, $R^2$= .845, F(1,48) = 4.96, p < .01. These results imply that knowledge transfers from the PC environment to timely PDA task performance; web use, computer use and web experience were each significant independent of chronological age. The only significant cognitive predictor, perceptual speed, suggests that the ability to transpose information from the instruction manual to the PDA interface quickened speed of performance.

*Cognitive errors*

Hierarchical regression for the number of cognitive errors observed during the delayed assessment indicated that age and reading comprehension each contributed significantly to the model and accounted for approximately 35% of the variance, $R^2$= .354, F(1, 48) = 7.82, p < .01. The influence of reading comprehension on later PDA performance might represent an effect of differential retention of the knowledge gleaned from practice such that those who successfully comprehended the instructions located in the manual were more likely

*Table 3. Zero-order Correlations of Predictors and Outcome Measures during Delayed Assessment; $^{*}$ p < .05. ** p < .01*

| Variables | Age | Delayed Time | Delayed Cognitive Errors | Delayed Motor Errors |
|---|---|---|---|---|
| Age | 1.0 | .65** | .5** | .36** |
| Perceptual Speed | -.77** | -.70** | -.41** | -.22 |
| Spatial Ability | -.67** | -.59** | -.44** | -.18 |
| Reading Comprehension | -.41** | -.57** | -.50** | -.19 |
| Working Memory | -.32* | -.42** | -.34* | -.25 |
| TCEQ-Web Use | -.43** | -.79** | -.30* | -.30* |
| TCEQ-Web Experience | -.34* | -.63** | -.22 | -.25 |
| TCEQ-Computer Experience | -.26 | -.76** | -.13 | -.03 |

to avoid cognitive errors during the delayed assessment. Based on the correlational analyses, the cognitive variables for working memory, spatial ability, and perceptual speed were entered into successive steps of the regression procedure but each failed to explain a significant amount of variance and will not be discussed further in this report.

**Usability Survey Analyses**

*Usability agreement ratings*

The mean usability agreement ratings for each age group are presented in Table 4. For all items, the mean agreement rating was above 4.80 which indicates that each age group on average held positive attitudes regarding their first experience with PDAs. T-test comparisons revealed age differences in perceived usability for five of the six statements. Younger adults rated the PDAs as significantly easier and simpler to use and rated the ease of learning to use the devices as higher than that reported by the older adults; $t(49) = 2.80$, $p < .01$, $t(49) = 3.42$, $p < .01$, and $t(49) = 2.46$, $p < .01$, respectively. Furthermore, younger adults also rated their effectiveness at entering medication scheduling information and error recovery as higher than that of the older adults; $t(49) = 2.69$, $p < .01$ and $t(49) = 4.65$, $p < .01$, respectively. Comparision of the remaining final mean ratings revealed no age differences on the statement regarding the likelihood of future use. Interestingly, the older adults ($M = 5.24$) rated their likelihood of future use as slightly, but not significantly higher than that reported by the younger adults ($M = 5.15$).

*Responses to open-ended questions*

Responses to the open-ended questions were transcribed and coded by two independent raters. Percentage agreement between the ratings of the coders was calculated to determine inter-rater reliability. The high percentage agreement which was 97.6% indicated that the coding scheme was adequately defined and reliable.

When asked for the BEST 'thing' about the PDA, the younger adults gave the following responses: 15 (58%) stated that the device was generally easy to use, 12 (46%) noted the small/portable size of the device, and 4 (15%) made reference to its potential use for personal organization. The older adults gave the following responses to the same question: 11 (44%) noted the small/portable size, 6 (24%) stated that the display was easy to read, and 3 (12%) noted that the quality of the menu/screen organization made the device easy to use. Thus, younger and older adults were generally in agreement regarding their opinion of the 'best' features of the PDA: portability and ease of use.

When asked for the WORST 'thing' about the PDA, younger adults gave the following responses: 9 (35%) disliked the small display screen, 5 (19%) commented on the monochrome display, while

*Table 4. Mean usability agreement ratings; Standard Deviations in parentheses; $^{*}p < .01$*

| Question | Younger | Older |
|---|---|---|
| Overall satisfaction | 6.42 (.64) | 5.72 (1.10)$^{*}$ |
| Simplicity of operation | 6.50 (.71) | 5.68 (.99)$^{*}$ |
| Ease of information entry | 6.62 (.50) | 5.96 (1.14)$^{*}$ |
| Ease of learning | 6.46 (.65) | 5.92 (.91)$^{*}$ |
| Error recovery | 6.31 (.84) | 4.80 (1.41)$^{*}$ |
| Likelihood of future use | 5.15 (1.91) | 4.24 (1.48) |

others 2 (8%) described problems using the stylus and 2 (8%) expressed difficulty reading the screen because of glare. The older adults gave the following responses to the same question: 5 (20%) disliked the small screen display, 4 (16%) expressed annoyance at the idea of keeping the device with them, and 4 (16%) described difficulty with the stylus. Less frequent responses included: small button size, unappealing appearance of the PDA, and poor screen contrast making the device display difficult to read. Thus, the age groups were generally in agreement that the small display size and difficulty manipulating the stylus reduced perceived PDA usability.

When asked to describe 'something NEW' in future versions of the PDA, 6 (23%) younger participants mainly expressed revisions to the visual layout (e.g., shape, color, button configuation) of the device, whereas 5 (19%) expressed a preference for a color screen. By contrast, 3 (12%) older adults wanted voice interaction, 2 (8%) wanted an emergency button (e.g., 911) for rapid-assistance communication, and 2 (8%) requested a larger, color screen. Less frequent responses included: backlighting of the display, privacy measures for medication information, and better sound features. Thus, other than both age groups expressing interest in a color screen, the two groups differed in their preference for future design. The younger adults wanted changes to the visual layout whereas older adults wanted future PDAs to include voice interaction and an emergency button.

## Discussion

Collectively, the results from the current experiment illustrate that older adults can learn to use PDA-based medication adherence applications if given the appropriate training. Furthermore, these findings indicated that many of the trends observed in previous studies that investigated desktop computer skill acquisition[29] with older adults were also present when PDA skill acquisition was explored. First, older adults required more time to complete the PDA-based medication entry task and committed more cognitive and motor errors than younger adults. Second, the PDA performance of older adults improved in terms of reduced time on task and error commission over time yet they failed to reach the same level of proficiency demonstrated by the younger adults. Finally, the qualitative responses from the survey of PDA usability indicated that despite age differences in perceived usability between young and older adults, the older adults retained their generally positive attitudes regarding device usage.

A primary motivation for this research was to determine whether usability-related issues might act as barriers to reduce or eliminate the potential benefits of using PDAs to enhance medication adherence. Although medication adherence was not tested directly in this experiment, the performance of the older adults was encouraging because they continued to improve over time with practice. Specifically, older adults completed the medication entry task more quickly and with fewer cognitive and motor errors as their expertise with the PDA grew. Importantly, the results of the regression analyses highlighted the need for effective training programs to maximize the usability of these handheld devices. Because perceptual speed and reading comprehension explained a portion of the variance in the dependent variables of time on task and cognitive error production, respectively, a number of training design recommendations might be considered to meet the needs of older adults. For instance, it is imperative that instruction does not progress at a rate too fast for older adults given their reduced processing speed[1]. Like-

December 2005, Vol 4, No 3



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wise, reading comprehension of instructions might be facilitated by the use of elaborative memory strategies and the use of explicit signals that highlight the main ideas and relations in the text[1,3]. Moreover, the finding that previous desktop computing experience is predictive of PDA skill acquisition suggests that it may be usefully applied to the development of training curricula. As new information is usually interpreted in the context of the pre-existing knowledge base, instructional materials should be presented using familiar terminology that capitalizes on the previous desktop experiences of older adults to facilitate learning[9,30].

Of course, the success of any technology-related training program will hinge on the attitudes of the older adults undergoing training[30,31]. Because previous research suggests that older adults who view computer technology as being useful to them are also more likely to use these devices[32], the findings from the usability survey are particularly insightful in determining whether older adults are likely to use PDAs outside of the laboratory. Analysis of the survey data revealed that although the mean usability ratings for five of the six statements did vary by age, older adults retained generally positive attitudes in spite of difficulties experienced during the medication entry task. Most surprising was the finding that older adults expressed a larger mean agreement than younger adults to the likelihood of using PDAs in the future. Anecdotally, these findings were further substantiated by several of the older participants using the money earned from study participation to purchase their own PDAs.

When asked to make utility judgments of PDA features, opinions of the 'best' and 'worst' features were generally consistent across age groups. However, the pattern of results for 'future' features are suggestive. While the younger participants appeared to be interested in altering the appearance of PDAs for more aesthetic purposes, the ideas of the older adults were more associated with improving function to compensate for reduced usability. Although both age groups described difficulty with using the stylus as one of the 'Worst' features of the PDA, only the older adult suggestion of voice interactivity approximates a design solution. Likewise, the request for an emergency assistance button suggests that older adults are aware of their potential need to use such a feature to compensate for physical vulnerability. Moreover, these data illustrate the value of using older adults to test the usability of devices such as PDAs because users in other age groups may also benefit from the inclusion of features that increase safety and privacy functionality[33,34].

While the results of this study are potentially informative for future PDA training curricula and hardware design, a number of limitations must be mentioned. First, this study was a best-case scenario—only relatively well educated and healthy older adults participated in this study. The average older adult will likely make more errors, and have greater difficulty which could result in clinically significant reductions in medication adherence. Second, the behavior of a relatively small sample of individuals from each age group was observed during a relatively brief period. The inclusion of a PDA skill assessment several weeks after the completion of training should be informative in determining how well such skills are maintained over time. Thus, caution must be used in interpreting trends in the data. Third, PDA use measures and perceived usability ratings were collected in the controlled environment of the laboratory where all of the participants were aware that they were being observed. To address these potential shortcomings, future investigations should consider observing the naturalistic behavior of larger, more diverse samples such as special needs populations within the older demographic where actual medication adherence data is collected over time to provide a more accurate assessment of skill retention and compliance.

Because older adults commonly express the desire to retain their functional independence[35], it is clear that one approach to assisting them to achieve this goal is through the development of technology tailored to meet their specific needs. Whether the promise of enhanced medication adherence can be realized by overcoming the usability barriers that older adults encounter with PDAs is an empirical question ripe for further research. Future work in this area will focus on efforts to reduce error production by isolating perceptual and cognitive factors associated with different types of errors. Through the identification of usability issues coupled with knowledge of design recommendations based on previous cognitive aging and human factors research, the design of new and emerging technologies such as PDAs may offer an opportunity to promote successful aging, improved safety, and personal empowerment through mundane tasks such as medication adherence.

## Acknowledgements

This work was supported by a Faculty Research and Development Grant to the first author from North Carolina State University. Portions of this work were presented at the 2004 Annual Meeting of the Human Factors and Ergonomics Society in New Orleans, Louisiana and at the 2005 International Conference of the Gerontechnology Society in Nagoya, Japan.

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