Abstract

LANZOLLA, VINCENT ROCCO. The usability of personal digital assistants as prospective memory aids for medication adherence in young and older adults. (Under the direction of Christopher B. Mayhorn.)

Medication adherence is essential to retaining functional independence into older adulthood. In the experiment reported here, 25 older and 26 young adults were asked to learn to use medication adherence software supported by a personal digital assistant (PDA). In addition to completing a battery of cognitive tests, each participant's PDA skill acquisition was assessed over time (i.e., during training, immediately following training, and after a delay). Consistent with previous research, older adults required longer to learn to use the PDA and committed more errors compared to younger adults. Cognitive predictors of PDA performance included spatial ability, perceptual speed, and particularly reading comprehension. Over time, age differences in PDA performance were reduced suggesting that older adults might benefit from the use of PDAs as prospective memory aids.

THE USABILITY OF PERSONAL DIGITAL ASSISTANTS AS PROSPECTIVE MEMORY AIDS FOR MEDICATION ADHERENCE IN YOUNG AND OLDER ADULTS

By

VINCENT LANZOLLA

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

DEPARTMENT OF PSYCHOLOGY

Raleigh

2004

APPROVED BY:

Dr. Sharolyn Converse-Lane   Dr. Michael S. Wogalter

Chair of Advisory Committee
Dr. Christopher B. Mayhorn

Biography

Vincent Rocco Lanzolla was born on March 30, 1966 in the Bronx, New York. In 1973, at the age of seven, his family relocated to Bari, Italy, where Vincent's father was born. After a year, Vincent's mother fled an abusive relationship and returned to the Bronx with him and his sister. His mother then suffered a severe nervous breakdown, later to be diagnosed with paranoid schizophrenia.

To his credit, his life's obstacles became his motivation to succeed. Vincent attended Public School 14, and Intermediate School 192. In 1984 he graduated from the prestigious Bronx High School of Science. Vincent went on to study Mass Communications at Iona College in New Rochelle, NY. He graduated in 1989 with a BA and embarked on a career in film production. In 1996, Vincent returned to school and attended Lehman College of the City University of New York. A year later he successfully completed yet a second Bachelor's Degree, this one in Psychology.

In 1997 Vincent relocated to Raleigh, NC, to attend North Carolina State University. Challenging himself with a continued motivation for success, he began his graduate career in Psychology at North Carolina State University. Unfortunately, along with his personal success came more personal challenges.

During his graduate career Vincent suffered through an abusive marriage that ended in divorce, developed and was diagnosed with diabetes, lost his mother piece by piece to stroke and mental illness, had his apartment completely cleaned out by thieves, was successfully treated for thyroid cancer, helped his uncle fight prostate cancer, and mentored a friend through her mental health challenges. His performance waxed and waned as he struggled to overcome this latest set of life's hurdles.

In the beginning there was little in the way of compassion and understanding from his administrators and mentors in the faculty. This too he triumphed over and sought out new guidance and support. A new diagnosis of ADD provided Vincent with insight into his personal struggles with performance. Triumph over this was slow and agonizing but worth the long nights. Those who took the time to say, 'can I help' and 'are you ok' will always be endeared to him. And for those who could only tell him how he was not performing satisfactorily, pointing out missed deadlines and failures, he looks at as further obstacles successfully surmounted.

Among his other accomplishments, Vincent is also a member of the Golden Key International Honour Society, Psi Chi Honor Society in Psychology, and Mensa. He has served as an Arbitrator for New York State's Automobile Lemon Law. Vincent has worked at International Business Machines as a cooperative student since 1999.

It is a shame that all through his school years teachers commented that he was very gifted, but "didn't apply himself." Maybe if they had looked closer and taken more time they would have noticed he had ADD and chronic depression due to vicious child abuse, and was struggling to do the best he could. He has persevered and triumphed and can today look back with pride on all the things he has accomplished and with excitement towards the gifts yet to come.

Acknowledgements

There are many people who have played a large part in helping me achieve this goal and deserve my thanks. Gus Ruscigno, my uncle, has been like a father to me through this, and has been an unending source of help and encouragement throughout my pursuit of this degree. Christina Colon, my ex-wife, who encouraged me to even begin this journey. I am so sorry that this thesis outlasted our marriage. Dr. Don Mershon was a friend and supporter when I felt like I had none. If it hadn't been for him, I may have given up. I have the utmost respect for him as a scientist and as a mensch. Mark Tallo and Jaime Vazquez, two old and very dear friends, who helped me through the darkest, most painful period of my life. Even though you were five hundred miles away, it felt like you were right there with me. Ray Lim, a new and dear friend, whose beer and cigars kept me sane. Stephanie Angle, for making me love her when I thought I may never love again. An endless supply of strength, support and coffee, thank you for believing in me when I had stopped believing in myself. My committee members, Mike Wogalter for helping conceive this project and Shari Converse Lane for her guidance and advice. And finally, my advisor, Dr. Chris Mayhorn, who helped me resurrect my graduate career. Without him, I would have given up. Thank you for making a good idea into a great project, and turning a thesis from an ordeal to an educational experience. Many advisors act like gatekeepers, I had a teacher. I can think of no higher compliment than that.

Table of Contents

List of Tables

The usability of personal digital assistants as prospective memory aids for medication adherence in young and older adults

The "graying of America" is a well-known phenomenon. By 2016, 47 million Americans will be age 65 and older; by 2025, 63 million Americans will be age 65 and older, representing nearly one fifth of the U.S. population (U.S. Census Bureau, 2000). It is important to note, that this is a worldwide phenomenon. It is estimated that by 2020, 24% of Europeans, 23% of North Americans, and 17% of East Asians will be 60 and older (Meyer, Talbot, Poon, Puskar, & Stubblefield, 1996).

As people age there are natural declines in physical and cognitive ability independent of disease. Declines in vision (e.g., acuity, contrast sensitivity), hearing (e.g., speech discrimination), and fine motor control are all common (Ivy, MacLeod, Petit, & Markus, 1992). Cognitive changes take place as well, including the decline of text comprehension (Craik & Rendell, 2000), poorer performance on verbal and spatial memory tasks (Salthouse, 1993), and greater difficulty in completing prospective memory tasks (Kidder, Park, Hertzog, & Morrell, 1997). Many of these declines are thought to be, at least in part, due to cognitive slowing (Salthouse, 1996). Older adults perform slower on tests of psychomotor speed, such as the Digit Symbol Substitution Test (Wechsler, 1997). This slowing is thought to impact many cognitive abilities by causing the contents of working memory to be forgotten before necessary processes are completed. Whatever the origin of the cognitive changes, these factors have direct impact on the design of any product intended for use by older adults.

In addition to the natural waning of physical and cognitive abilities, chronic conditions (e.g. osteoarthritis, diabetes, hypertension, hypercholesteremia, arteriosclerosis) also take their toll. Approximately 80% of all U.S. seniors have one chronic condition and 50% have at least two (Arslan, Atalay, & Gokce-Kutsal, 2002). With the onset of multiple maladies come multiple medications. The average older adult uses four to five prescriptions concurrently (Moore & Beers, 1992). It is not uncommon for older adults to be taking 10 or more medications (Park & Kidder, 1996).

<u>Aging and Medication Adherence</u>

Medication adherence is defined as a patient using doctor prescribed medication as directed: taking the medication at the correct times, at the indicated dosage, following any special instructions (Park & Kidder, 1996). Estimates of strict patient medication adherence vary from 26% to 59% (Malhotra, Karan, Pandhi, & Jain, 2001). An estimated 71% of non-compliance is under use of the medication, in large part due to forgetfulness (Kidder et al., 1997). Complexity of schedule, number of prescribing physicians and number of medications all tend to correlate with non-compliance (Malhotra et al., 2001; Park & Kidder, 1996). In a best-case scenario, lack of medication adherence leads to diminished or complete loss of efficacy of the medication. In a worst-case it can lead to illness, hospitalization, or loss of life.

Much previous research has focused on developing interventions to increase medication adherence. Interventions investigated include: automated phone messages to serve as reminders (Leirer, Morrow, Tanke, & Pariante, 1991); attempting to improve doctor-patient communication (Zola, 1986); patient education on setting up and the importance of their medication schedule (MacDonald, MacDonald, & Phoenix, 1977); pill organizers (Park, Morrell, Frieske, Blackburn, & Birchmore, 1991); printed schedules and organizers individually and in conjunction (Park, Morrell, Frieske, & Kincaid, 1992);

pictorial-based instructions (Morrell, Park, & Poon, 1990). Each method has met with varying degrees of success.

One of the most effective interventions was the use of voicemail reminders (Leirer et al., 1991). In that study, older adults were asked to adhere to a simulated medication schedule over a two-week period. The treatment group received an automated voicemail message reminding them when it was time to take a medication and exactly what was to be taken. The authors report that the error rate for the control group was 14.2%, and 2.1% for the treatment group. Not only was this significant, but it was also well below the 10% error threshold that was the upper limit of previous work. To understand why this intervention was effective, it is important to understand the underlying cognitive factors involved in this medication adherence task. Chief among these is prospective memory.

<u>Prospective Memory as a Cognitive Predictor of Medication Adherence</u>

In the literature, remembering to take medication is a paradigmatic example of a prospective memory task (Park & Kidder, 1996). "Prospective memory can be thought of as processing that supports the realization of delayed intentions," (Ellis, 1996). In lay terms, it is remembering to perform an action some time in the future. "I have to get bread on the way home," and "I need to ask my boss for next Monday off," are both examples of prospective memory tasks—remembering to do something at a later time. Prospective memory has a retrospective component as well. The individual must remember to do something (the prospective component) and the content of the action, e.g. what type of bread the family likes (the retrospective component) (Brandimonte & Passolunghi, 1994). Older adults taking multiple medications face a daunting prospective memory task: each medication can have a different administration schedule, different dosages, and radically different special administration instructions (e.g., take before bed, take three times a day, take 20 minutes after meals, take with food, avoid dairy products). Effective medication adherence interventions will need to support both the prospective and retrospective components of prospective memory (Mayhorn, Rogers, & Fisk, in press).

There is a significant interaction between prospective memory task complexity and age. Task complexity is affected by several factors: dedication of finite cognitive resources to other tasks, the number of prospective memory tasks to be remembered, and the amount of information contained in a memory task (Einstein & McDaniel, 1990). Older adults show similar performance on prospective memory tasks to younger adults at lower complexity tasks. The older adults, however, suffer increasing performance deficits as task complexity increases (Einstein & McDaniel, 1990; Kidder et al., 1997; Maylor, 1996). Thus older adults may have difficulty adhering to complicated medication regimens, where multiple medications are being taken in different quantities, at different times.

A fundamental distinction made in the literature is whether a prospective memory task is event-based or time-based. A time-based task is one that is performed at a specific time or after a specified amount of time elapses (Einstein, Holland, Guynn, & McDaniel, 1992; Einstein & McDaniel, 1990). It is more resource dependent, as the individual must remember that a particular time is important and then why it is important. An event-based task is performed when some external event occurs (Einstein et al., 1992; Einstein & McDaniel, 1990). Event-based tasks are less resource dependent as an external event serves as the cue, not an internal process. An example of this transformation is leaving letters that need to be mailed by the front door (Mayhorn et al., in press). Seeing the letters on the way out reminds you that they need to be brought to the mailbox. Time-based tasks have less environmental support. They are for the most part self-initiated, relying on memory to initiate action. An example of a time-based task would be, call home at 4:30 (Mayhorn et al., in press). Age-related deficits in prospective memory are greater for time-based tasks than for event-based (Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997).

Improving Prospective Memory with Environmental Support

One way to assist in the accomplishment of prospective memory tasks is to provide environmental support. By providing ‚information in the world and not in the head," demands on limited resources (i.e., working memory) are reduced (Morrell, 2002). Remembering something can be described as an interaction between external stimuli and internal (resource limited) processes (Craik & Jennings, 1992). Deficits in prospective memory (internal, resource limited) may be compensated for by providing additional salient reminders (external stimuli). When using external reminders, older adults perform as well or better than younger individuals on prospective memory tasks (Craik & Jennings, 1992). External reminders transform time-based prospective memory tasks to event-based prospective memory tasks.

Environmental supports fall into one of two categories, passive and active (Herrmann, Brubaker, Yoder, Sheets, & Tio, 1999). Passive supports, such as a written schedule, will remind a person of what has to be done and when it has to be done. Unfortunately, passive supports can be overlooked or forgotten—an unread note cannot remind. Active supports call attention to themselves. An alarm clock signals that an important time has arrived. Active reminders have been shown to be more effective in facilitating prospective memory: automated phone messages, sent to patients as reminders to take their medication, significantly increased patient medication adherence (Leirer et al., 1991). Passive supports have shown benefit beyond simple reminders though. In a study designed to ascertain the usability of medication organizers, it was found that the organizers seemed to facilitate patients' comprehension of their drug regimens (Park et al., 1992). In that study, participants were first asked to write out their medication schedule for a 24-hour period. This was done to establish their comprehension of their medication regimen. Participants were then asked to load various medication organizers according to their understanding of their schedule. The participants made fewer errors loading the organizers than they did when writing out their schedules. The authors postulated that the organizers facilitated the participants' comprehension.

Personal Digital Assistants as Environmental Support

Personal Digital Assistants (PDAs) have been described as the most effective reminding device currently available (Herrmann et al., 1999). PDAs have the potential to provide significant benefit to anyone on a complicated medication schedule. They can be used to map out a medication administration plan, relieving the individual of having to rely on memory to hold their schedule (passive support). The PDA can serve as a source of active support by activating an auditory/visual/tactile alarm to announce a scheduled medication dosage, facilitating remembering to remember. The PDA can also relieve the retrospective memory load of prospective memory tasks by storing all pertinent medication information—dosage, special instructions, etc.

Common fallacies are that older adults are not interested in learning about computers and that their extreme computer anxiety adversely affects their ability to learn (Rogers, Mayhorn, & Fisk, in press). Research has shown that this is not the case. Older adults have great interest in learning about computers (Adler, 2002; Morrell, Mayhorn, & Bennett, 2000) and have demonstrated the ability to acquire basic computer skills when provided adequate instruction (Morrell, Park, Mayhorn, & Kelley, 2000). While computer anxiety is thought to hinder learning about them (Charness, Schumann, & Boritz, 1992; Marcoulides, 1991; Tseng, Tiplady, Macleod, & Wright, 1998), older adults' anxiety levels have been shown to be similar to their younger counterparts (Rogers et al., in press). Additionally, it has been reported that significant positive change in attitude toward computers can be effected in older adults by giving them elementary education on using them (Morris, 1994). This would indicate that even if certain older adults were negatively biased toward computers, this could be ameliorated with education.

Whether or not older adults will be interested in using PDAs remains an empirical question, ripe for investigation. Previous research indicates that older adults are motivated to use new technologies more by perceived benefits than novelty or curiosity. They appear to do a cost-benefit analysis when it comes to learning new things, weighing the potential benefit against the potential problems. However, once it is clear that there is benefit to be gained they will attempt to learn a new technology (Melenhorst, Rogers, & Caylor, 2001). They tend not to be early adopters of new technology, but once it has matured, older adults tend to embrace it (e.g. videocassette recorders) if the benefits outweigh the costs of using/learning it (Adler, 2002). Perhaps older adults have been perceived as technophobes simply because they are not technophiles. With the proper introduction and training older adults may react positively to the introduction of the PDA as a memory aid.

Obviously the potential benefits of PDA usage by older adults are great, yet the realization of this potential is dependent on the usability needs of this special population. The small size of PDAs makes them easily portable. A touch-screen interface is thought to be easier to learn and more intuitive than a conventional window and mouse paradigm (Tseng et al., 1998). Palm-based PDAs are now available for under $100, making them accessible to most interested individuals.

The affordability, portability, and user interface of PDAs may have inherent usability trade-offs for older adults. For instance, the small LCD displays 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. The small screen also forces users to either do a great deal of scrolling or nest information several levels deep, placing it many taps away, complicating navigation (Norman, 1990). While a good deal of research has been conducted on older adults and their use of computers little has focused on their use of hand-held computers. It has been reported that older adults have difficulty with text entry on PDAs (Wright et al., 2000), but that study did not address the overall usability of the devices. Given these facts, can PDAs be of benefit to older adults?

Cognitive Predictors of Older Adults' Computer Performance

The same cognitive abilities that demonstrate age-related decline are often the same abilities that are thought to be important in the learning and use of computers. Spatial ability has long been shown to be an important predictor of computer performance (Vicente, Hayes, & Williges, 1987). Reading comprehension has been shown to be a correlate of computer performance (Vicente et al., 1987) and is fundamental in the understanding of written instructions. Working memory is a limiting factor in how much information is remembered and can be manipulated. Perceptual speed would be a limiting factor in how fast they can react to information presented, and as it is an indicator of cognitive slowing, may also correlate strongly with performance of other cognitive abilities.

Increasing health concerns represent one context where these cognitive changes might significantly impact the well-being of older adults. Declines in physical and cognitive abilities decrease their ability to care for themselves, yet due to age-related illnesses, this is when many need the most care. Technology can provide assistance by compensating for declines in certain abilities, but the same declines reduce their ability to utilize technology. By contrasting the performance of young and older adults, it may be possible to isolate important variables that negatively affect older adults' interaction with technology. The purpose of this study was to determine if the inherent limitations of PDAs eliminate their potential benefits as memory aids for older adults.

Method

Participants

Twenty-six participants were students from the subject pool available at North Carolina State University, ages 17 to 23, $M = 18.65$, $SD = 1.36$. Twenty-five participants were older adults, ages 60 to 76, $M = 67.36$, $SD = 5.24$, recruited from the community through computer education classes. 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 confound of prior PDA experience.

For analysis of the cognitive testing data, alpha levels of all analyses were set to .05. T-tests of the demographic information revealed patterns consistent with previous research. The older adults performed less well than the younger adults (see Table 1) on measures of spatial ability, working memory, reading comprehension and perceptual speed. The older adults did, however, outperform their younger counterparts on the test of vocabulary. Older adults report less computer, web and general technology use. They reported greater interest in learning about computers and saw computers as more dehumanizing.

Demographic information was obtained concerning self-reported health. There were no significant age differences in self-reported health, $p = .36$. When they evaluated their general health on a scale of 1 ("Poor") to 5 ("Excellent"), mean responses from both age groups approximated 4 ("Very Good"). No significant differences were found in other computer attitudes or, interestingly, in computer anxiety. Thus, the participants were relatively healthy individuals who held generally consistent attitudes toward computers. As computer anxiety is a powerful predictor of computer training success

(Charness, Schumann, & Boritz, 1992), the lack of a statistical effect here demonstrates that both age groups held generally positive attitudes toward learning to use the PDAs.

Table 1

Significant T-tests of Population Parameters

	Mean Scores (SD)						
	Younger		Older		t	df	Sig. (2-tailed)
TCEQ – Technology Usage	22.46	(3.04)	20.6	(3.03)	2.192	49	.033
TCEQ - Computer Experience	35.54	(3.4)	30.08	(11.51)	2.316	49	.025
Web Use	13.38	(1.44)	9.48	(4.83)	3.943	49	0
Web Experience	20.19	(6.18)	13.96	(8.99)	2.894	49	.006
CAQ - Dehumanization	14.12	(3.71)	11.44	(4.13)	2.434	49	.019
CAQ – Interest	20.5	(2.63)	22.24	(1.92)	-2.691	49	.01
Vocabulary	28.81	(4.35)	32.72	(4.68)	-3.093	49	.003
Working Memory	36.04	(12.94)	29.08	(9.22)	2.204	49	.032
Reading Comprehension	31.88	(5.49)	25.24	(9.32)	3.119	49	.003
Spatial Ability	13.77	(3.02)	7.8	(3.58)	6.44	49	0
Perceptual Speed	70.27	(8.76)	49.48	(8.78)	8.464	49	0

Stimulus Materials

Participants were asked to enter information into a popular medication tracking software package on a PDA. The PDAs provided by the experimenter were the Palm Zire, utilizing the Palm operating system, with a 160x160 pixel monochrome display. The On-Time Rx software is advertised by the manufacturer as intuitive and easy to use (AmeliaPlex, 2003). The on-screen keyboard was used as it is On-Time Rx's default method of data entry. Medication tracking was chosen as it should be a salient task for the older adults, so any difference in performance between the two groups would be more likely due to age-related changes in abilities and not familiarity or motivation. It is also likely to be a very important type of PDA application for older adults.

A demographic questionnaire was furnished to provide information concerning age, education, and health. A computer attitudes questionnaire was administered (Jay & Willis, 1992). The Computer Attitude Questionnaire (CAQ) consisted of five subscales: Interest in Computing, Computer Self-Efficacy, Dehumanization, Utility, and Comfort. A measure of computer and technology experience was administered. The Computer Experience Questionnaire (TCEQ) (Kelley, Morrell, Park, & Mayhorn, 1999) asked participants about their experience with computers and general electronic technology such as Automatic Teller Machines (ATMs) and home security systems.

A battery of cognitive tests was administered to participants and included measures of vocabulary (Shipley, 1986), reading comprehension (Brown, Fishco, & Hanna, 1993), spatial abilities (Ekstrom, French, & Harman, 1979), working memory (LaPointe & Engle, 1990) and perceptual speed (Wechsler, 1997). A test of logical ability, the Reasoning Questionnaire from the Everyday Cognition Battery (ECB) (Allaire & Marsiske, 1999) was used as a distracter task during day two of testing.

To understand the detail and complexity of PDA usage, particularly the usage of the medication adherence software to be used in this study, a task analysis was conducted (see Appendix A). It was suspected that the PDA and the software were not quite as easy to learn as advertised especially because they did not come with written instructions. Pilot work with older adults showed they had great difficulty learning to use the program through trial and error. For comparison, the older adults ($n = 2$) in the pilot group made an average of 37 cognitive errors in the practice trial, $SD = 15.56$; as compared to the experimental group's 4.52, $SD = 4.39$ which will be presented in the following Results section. At the initial assessment, the pilot group averaged 21 errors, $SD = 7.07$;

compared to the main group's 5.76, SD = 3.62. The pilot group still lagged far behind at the delayed assessment with an average of 12.5 cognitive errors, SD = .71; and the experimental group's 3.6, SD = 2.0. Reports of frustration to the point of giving up, and confusion as to whether the task was even completed, were observed. While one would normally expect that the number of errors would be substantially greater in the first assessment due to the use of trial and error as a means of learning the interface, such a substantial difference in the final assessment showed that the pilot group, not having an instruction manual, was at a significant disadvantage.

Based on the pilot findings, an illustrated manual (see Appendix B) was constructed based on the task analysis to teach the participants to use the PDA software. Digital copies of the instruction manual and complete dataset are available from the author upon request. The manual illustrated every step necessary to enter a medication's information (see Appendix C). Participants learned to use the PDA and software by following the manual precisely one time. This activity learning method has been shown to be more effective than just reading instructions for older adults (Sterns, 1986).

A stylus tester program was developed for this project. It was utilized 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.

Design

A 2 (age: young 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.

Procedure

All participants were informed of the nature of the testing and explained their rights as participants, they then signed consent forms. On the first day of testing, groups of 3-10 participants completed a demographic questionnaire, Computer Attitude Questionnaire (CAQ), The Computer Experience Questionnaire (TCEQ), and the cognitive battery. This session lasted for approximately two hours.

On the second (non-consecutive) day of testing, participants were individually tested for near-normal vision (defined as 20/40 corrected), and ability to accurately use a stylus. They were then tested for their ability to learn the procedures necessary for usage of 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 ECB Reasoning Questionnaire (Allaire & Marsiske, 1999), was then given as a distracter task, for a period of 25-30 minutes to prevent rehearsal of the PDA procedure. 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 tracked time on task and error production. Errors were classified as either cognitive or motor control. Some examples of cognitive errors are leaving out a step (e.g. not setting the schedule to repeat), or adding a step (e.g. changing the frequency when the default is correct). 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.

After the testing had concluded, participants were debriefed, and given contact information in case they had concerns or questions.

Results

Analyses of PDA Task Performance

Alpha levels of all analyses were set to .05. 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 took less time across trials (see Table 2). Tukey's HSD test showed that participants of both age groups took more time in the practice assessment (M = 465.91 seconds), than in initial (M = 284.53 seconds) which in turn was greater than the amount of time spent on the delayed assessment (M = 165.91seconds).

The presence of the interaction showed that the generalized decrease in time was not as consistent for the young adults as for the older adults, most 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 make large strides. 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.

Table 2

Group Means and Standard Deviations for Time on Task, Cognitive and Motor-control Errors

Time of Assessment	Group	Time on Task (seconds)		Cognitive Errors		Motor Errors	
		M	SD	M	SD	M	SD
Practice	Young	308	63	.92	1.3	1.27	1.34
	Old	623	216	4.52	4.39	4.04	3.88
Initial	Young	152	54	3.31	2.35	1.12	1.37
	Old	416	191	5.76	3.62	3.38	3.50
Delayed	Young	97	15	1.92	1.16	1.04	2.4
	Old	234	106	3.60	2.00	2.64	2.83

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, $F(2, 98) = 2.55$, $p = .08$. The younger adults made fewer cognitive errors across trials (see 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, $F(2,98) = 3.16$, $p = .05$; the interaction of age and time of assessment was not significant, $F(2,98) = 1.66$, $p = .2$. The older group had a much larger variance, but the means of the last two assessments are quite close. Each age group's motor control errors declined across trials (see Table 2).

Correlation Analyses

A series of zero-order correlations were performed on the demographic data, cognitive measures and the dependent variables for each assessment (practice, initial, delayed). The dependent variables were time on task, cognitive errors and motor-control errors.

Age was significantly correlated with all of the DV's; time on task, cognitive errors and motor control errors; ranging from -.29 to -.63 (see Table 3). Web use was the strongest correlate for the DV's, from -.3 to -.79 (see Table 3). Among the cognitive measures, the Digit-Symbol Substitution (DSS) test was the strongest correlate for the DV's, from -.33 to -.71. The DSS, a measure of perceptual speed, was also the strongest correlate of age.

Table 3

Zero-order Correlations of Predictors and Outcome Measures

	AGE	Practice Time	Practice Cognitive Errors	Practice Motor Errors	Initial Time	Initial Cognitive Errors	Initial Motor Errors	Delayed Time	Delayed Cognitive Errors	Delayed Motor Errors
Perceptual Speed	-.77(**)	-.71(**)	-.56(**)	-.32(*)	-.67(**)	-.33(*)	-.32(*)	-.7(**)	-.41(**)	-.22
Spatial Ability	-.67(**)	-.66(**)	-.56(**)	-.3(*)	-.69(**)	-.33(*)	-.17	-.59(**)	-.44(**)	-.18
Reading Comprehension	-.41(**)	-.62(**)	-.6(**)	-.08	-.62(**)	-.43(**)	-.06	-.57(**)	-.50(**)	-.19
Working Memory	-.32(*)	-.4(**)	-.37(**)	-.21	-.34(*)	-.16	-.05	-.42(**)	-.34(*)	-.25
Reasoning	-.12	-.32(*)	-.24	.02	-.33(*)	-.11	.05	-.25	-.21	.03
Web Use	-.43(**)	-.65(**)	-.42(**)	-.25	-.79(**)	-.16	-.35(*)	-.79(**)	-.3(*)	-.3(*)
Web Experience	-.34(*)	-.59(**)	-.4(**)	-.26	-.66(**)	-.12	-.36(*)	-.63(**)	-.22	-.25
Computer Experience	-.26	-.52(**)	-.34(*)	.01	-.76(**)	-.23	-.11	-.76(**)	-.13	-.03
Technology Use	-.27	-.39(**)	-.25	-.08	-.49(**)	-.17	-.14	-.57 (**)	-.25	-.07
Computer Attitudes - Dehumanization	-.32(*)	-.09	.02	-.05	-.11	-.16	-.27	-.09	.06	-.08
AGE	1	.69(**)	.53(**)	.47(**)	.66(**)	.39(**)	.42(**)	.65(**)	.5(**)	.36(**)
Computer Attitudes - Anxiety	.02	.23	.19	-.12	.32(*)	.14	.08	.29(*)	.29(*)	.19
Computer Attitudes - Comfort	-.17	-.32(*)	-.17	.01	-.52(**)	-.08	-.14	-.54(**)	-.25	-.22

* p < .05. ** p < .01.

Regression Analyses

A series of hierarchical regressions were performed on the time each participant took to complete the task. The outcome measures were time on task, cognitive errors and motor errors for practice, initial and delayed assessment. The standard predictors of computer performance have not yet been assessed in a personal digital assistants task environment. Therefore, the number of predictor variables and their ordering in each hierarchical regression were guided by the correlational analysis (see Table 3). To control for age, it was entered first in all regressions.

Time on Task. For time on task during the practice assessment; age, perceptual speed, spatial ability, web usage and reading comprehension each made significant contributions to the overall R^2, accounting for nearly 72% of the variance, $R^2(1,48) = .719$, $p = .024$ (see Table 4). Age, being the first variable entered, should have contributed to the model. Spatial ability has long been known to be a mitigator of computer ability (Gomez, Egan, & Bowers, 1986; Vicente et al., 1987). While perceptual speed is not normally associated with computer ability, its significance is not surprising when one considers the nature of the task; this point will be elaborated in the Discussion section. The significance of reading comprehension indicates that an instruction manual is important: participants' ability to glean information from it was a key determinant of their success. Interestingly, web use and not computer use was significant.

Table 4

Regression of Predictor Variables on Time on Task

	Predictors	ΔR^2	Cumulative R^2	F	β
Practice	Age	.474*	.474	39.66	.162
	Age + Perceptual	.076*	.55	7.302	-.267
	Age + Perceptual + Spatial	.051*	.601	5.324	-.131
	Age + Perceptual + Spatial + Web Usage	.079*	.68	10.077	-.173
	Age + Perceptual + Spatial + Web Usage + Reading	.039*	.719	5.536	-.316*
Initial	Age	.435*	.435	33.879	.242
	Age + Web Use	.311*	.746	52.726	-.162
	Age + Web Use + Comp Exp	.066*	.812	14.819	-.481*
	Age + Web Use + Comp Exp + Spatial	.007*	.819	1.493	-.125
	Age + Web Use + Comp Exp + Spatial + Perceptual	.007*	.826	1.637	-.124
	Age + Web Use + Comp Exp + Spatial + Perceptual + Web Exp	.006*	.833	1.508	.046
	Age + Web Use + Comp Exp + Spatial + Perceptual + Web Exp + Reading	.02*	.853	5.273	-.262*
Delayed	Age	.424*	.424	36.137	.266*
	Age + Web Use	.312*	.736	56.773	-.249
	Age + Web Use + Computer Exp	.07*	.807	17.142	-.439*
	Age + Web Use + Computer Exp + Perceptual	.021*	.828	5.544	-.254*
	Age + Web Use + Computer Exp + Perceptual + Web Exp	.017*	.845	4.959	.169
	Age + Web Use + Computer Exp + Perceptual + Web Exp + Spatial	.001	.845	.178	.106
	Age + Web Use + Computer Exp + Perceptual + Web Exp + Spatial + Reading	.009	.854	2.51	-.063

* $p < .05$.

Hierarchical regression for the initial assessment time showed that; age, web use, computer experience, spatial ability, perceptual speed, web experience and reading comprehension each made significant contributions to the model, $R^2(1,48) = .853$, $p = .027$ (see Table 4). These results imply that there is a good deal of knowledge transfer from the PC environment to PDAs; web use, computer use and web experience were each significant. Reading comprehension again being significant seems to emphasize the importance of quality instructional materials.

In the delayed assessment; age, web use, computer experience, perceptual speed, web experience, and spatial ability all added significantly to the model, accounting for almost 87% of the variance, $R^2(1,48) = .869$, $p = .007$ (See Table 4). The lack of contribution for reading comprehension suggests that participant's knowledge progressed beyond the need for instructional material. The continued significance of web use, computer use and web experience continues to illustrate the importance of knowledge transfer from the PC realm. With reading comprehension having fallen by the wayside, perceptual speed indicates that the task had become familiar enough that the data entry was now more a question of transposition of information from the instruction sheet to the PDA.

<u>Cognitive Errors.</u> Hierarchical regression for the practice assessment revealed that age and reading comprehension each contributed to the model, $R^2(1,48) = .451$, $p < .001$ (see Table 5).

In the initial assessment regression, age and reading comprehension each contributed to the model, $R^2(1,48) = .238$, $p = .024$ (see Table 5).

Table 5

Regression of Predictor Variables on Cognitive Errors

	Predictors	ΔR2	Cumulative R2	F	β
Practice	Age	.278*	.278	18.84	.089
	Age + Reading	.174*	.451	15.207	-.393*
Initial	Age	.152*	.152	8.762	.257
	Reading	.087*	.238	5.464	-.319*
Delayed	Age	.248*	.248	16.174	.469*
	Age + Reading	.105*	.354	7.822	-.276
	Age + Reading + Spatial	.003	.357	.248	-.019
	Age + Reading + Spatial + Perceptual	.001	.358	.054	.072
	Age + Reading + Spatial + Perceptual + Working Memory	.002	.359	.106	-.081
	Age + Reading + Spatial + Perceptual + Working Memory + Web Use	.002	.362	.161	.165
	Age + Reading + Spatial + Perceptual + Working Memory + Web Use + Anxiety	.045	.407	3.274	.268

Note: the addition of Anxiety approached significance at .077
* $p < .05$.

In the delayed assessment, age and reading comprehension each contributed to the model, $R^2(1,48) = .354$, $p = .007$ (see Table 5). Computer Anxiety, was the last variable entered into the model, and approached significance, $R^2(1,48) = .407$, $p = .077$; $t(49) = .268$, $p = .077$. Because anxiety is a known mitigator of learning (Charness et al., 1992; Marcoulides, 1991; Tseng et al., 1998), computer anxiety, or perhaps generalized anxiety, or both, may be factors here. Reading comprehension was the only statistically significant cognitive predictor for cognitive errors.

Motor Control Errors. In each assessment, age was the only significant contributor to the model. Practice assessment, $R^2(1,49) = .219$, $p = .001$; initial assessment, $R^2(1,49) = .174$, $p = .002$; delayed assessment, $R^2(1,49) = .129$, $p = .001$ (see Table 6). The variability associated with age decreases over time, dropping from almost 22% to less than 12%. Clearly there are other, untested predictors at work here.

Discussion

The use of PDAs by older adults appears to be a promising avenue for increasing medication adherence. However, the following findings illustrate that general usability and cognitive issues associated with these devices should first be addressed with older adult populations before technological interventions can be implemented. First, older adults took more time to complete the assigned task, though they did make large strides and their improvement across evaluations was greater than that of the younger adults. Second, the older adults made more cognitive errors, but the two groups displayed similar patterns of improvement across evaluations. Third, older adults also made more motor control errors than the younger group, again with similar patterns of improvement across evaluations. Fourth, web use and perceptual speed were the strongest correlates of the dependent variables. Fifth, regression analysis revealed that web use, perceptual speed and reading comprehension were significant predictors of time on task. Sixth, reading comprehension was the only significant predictor of cognitive errors. Seventh, there were no predictors of motor control errors.

Clearly, these findings indicate that, even with instructions and practice, older adults' performance did not approximate that of the younger group. While examination of the dependent measures (i.e., errors and time on task) in this experiment revealed significant main effects of age, the results suggest that older adults can learn to perform PDA-based medication adherence tasks. Consistent with general slowing models of cognitive aging, it appears that older adults simply require more time to complete the tasks. Although analysis of error production revealed that older adults make more errors than young adults, it should be noted that these errors declined with practice over time. This is consistent with prior research in a PC environment that showed motor errors can be reduced with practice (Mayhorn, Stronge, McLaughlin, & Rogers, 2004).

In previous work on cognitive predictors of computer learning (Vicente et al., 1987), multiple predictors were correlated with performance, but regression analysis showed that only spatial ability was a significant predictor. In the present study, perceptual speed and spatial ability were all consistently (across assessments) shown to be predictors of time on task, and reading comprehension was significant in the practice and initial assessments but not the delayed. Thus, the nature of the task appeared to change over time. The instructions seem to be an important part of the learning process—the software is not "just walk up and use" as it was advertised. The declining importance of reading comprehension to time on task suggests that the PDA interface is simple enough to be quickly learned yet the initial provision of instructions is a necessity that should be considered by the manufacturer. An apt characterization of the PDA interface might be “simple but not intuitive.” Perceptual speed should logically be significant—in practice, participants had to compare the manual illustrations with the PDA display, and transpose the information. While use of the manual was optional in initial and delayed assessment, the participant still had to transpose the medication information presented into the PDA. Also, if perceptual speed truly is an indicator of general cognitive slowing, for this reason alone it should be a significant predictor of time on task. Prior computer experience in general, and web usage in particular, were predictors. PDAs are generally thought to be easy to use because their touch-screen interface is more intuitive. The advantage of prior computer experience seen here seems to indicate that they are easy to use because their interface is familiar. The strength of web use and web experience as predictors gives the impression that the World Wide Web’s (WWW) hypertext-based interface would appear to be a very good analog of the PDA studied here. Since crystallized intelligence remains intact as people age, and older adults tend to interpret new information in light of previous knowledge (Mayhorn et al., 2004), using terminology and paradigms from the Web to present instructional material may be of significant benefit, particularly for older users.

For cognitive errors, reading comprehension was the only significant cognitive predictor of performance. This was at first somewhat surprising as spatial ability has long been the gold standard of computer learning predictors. However, when one considers that the PDA interface is not nearly as feature rich as a typical PC interface, it stands to reason that spatial ability would be less important. There are simply fewer places to go, and fewer ways to get there: The menu bar, omnipresent in a PC environment, is hidden in the PDA; "right click" context menus are not used in the PDA interface; there are no "windows" in a PDA, the PDA is the window, and there is only one. The PDA interface would seem to have more in common with HTML-based web pages than with traditional PC interfaces. For instance, web browsers do provide a context menu yet their use is certainly not necessary to navigating the web: navigation is a one-click affair quite similar to the PDA in this regard.

The nature of the task may also be a mitigating factor in the importance of reading comprehension. Essentially the participants are reading a set of instructions (the name, dose and schedule of a medication), and the PDA is querying them for answers to questions about those same parameters. Thus, in this instance, effective use of environmental support is dependent on the user's reading comprehension ability.

The importance of an instruction manual and prior experience points to a simple solution for improving usability of PDAs for users of all ages—use of a wizard. While not tested in this experiment, wizards are an interface tool that is used to accommodate users as they attempt new, or rarely performed tasks (Scanlon, 1997). A wizard presupposes that the user has little to no experience with the task they are about to perform, and provides environmental support. Rather than ask the user to input a screen-full of information, a well designed wizard will present a few items at a time, in a logical order, explain each item, and step the user through the task of information input. Use of a wizard to sequentially prompt the user for input would compensate for not having an instruction manual, relieve cognitive load associated with working memory deficits by reducing trial-and-error learning, and reduce the importance of prior experience.

While a certain amount of variance in motor control errors was expected, the amount of variance observed was unexpected. It was thought that the use of the stylus trainer as a screening tool would limit the variability. Further examination of the issue revealed that the programmer who developed the trainer program used an on-touch paradigm. The stylus trainer recorded a successful hit as the participant touched the screen. The PDA on the other hand, uses an on-release paradigm. When a button (or any other on-screen control) is touched, selection is not acknowledged until the pen is lifted. The pen must touch, and release the same target. If the pen is moved off the target in between, selection is not acknowledged. In effect, the user must hit the target twice, on-touch, and on-release. Selecting a target in the PDA interface was much more difficult for users with an unsteady hand, than it was in the stylus trainer. Compounding this was the small size of the targets—as target size decreases, the difficulty in selecting the target increases (Fitts, 1954). On-release is essentially forcing the participants to perform two Fitts' Law tasks, hitting a target, and releasing the same target. Targeting was further complicated by the flexibility of the stylus. Other, more substantial styli have a metal body with a plastic tip. The stylus that came with the Zire PDAs was made of a rather flexible plastic, presumably for cost reasons. As people are wont to do when they have trouble selecting a target, they started to press harder. The stylus could be seen bending when pressed firmly on the screen. Even though they had hit the target, and maintained a steady hand, the deflection of the stylus was enough to move the tip off the target and cause a selection failure. Based on this finding, developers would be wise to consider an on-touch paradigm when designing for older users, and providing a rigid stylus with a soft tip.

One very common error was missing the scroll-down arrow in a drop-down field. If missed to the right, participants would frequently miss the drop-down entirely, and the interface closes the drop-down. If missed to the left, the (wrong) item to the left of the arrow was selected, and the drop-down closed. This was a source of great frustration for some individuals. Developers targeting older adults should consider using compensatory interface constructs similar to area cursors and sticky icons (Worden, Walker, Bharat, & Hudson, 1997).

A very interesting observation was made by a study participant. He explained that penmanship was a hobby of his, and that of late he noticed a bit of a tremor occasionally while writing. He observed that the screen of the PDA was very slick, and seemed to exacerbate this. He reasoned that a surface with a higher coefficient of friction may help steady an unsteady hand. This may be particularly important in instances where handwriting recognition is used. Such user feedback is a valuable source of information ripe for further empirical research.

One of the limitations of this study was that the older adults who participated were a self selecting population. They were recruited from local computer education classes, and showed a great deal of interest in learning more about computers. Another limitation was that only relatively high-ability older adults participated in this study. This study was a best-case scenario. The average older adult will likely make more errors, and have greater difficulty. Follow-on studies should look at special needs populations within the older demographic, and at potential users with less enthusiastic interest in technology.

Upcoming work in this area will focus on efforts to further reduce error production by isolating perceptual and cognitive factors associated with different types of errors. It is important to ascertain whether reading comprehension is an important factor in PDA use, or if it was simply an artifact of the task used here. Future research should also look toward establishing reliable predictors of motor control errors. Only then will progress be made in accommodating users with motor-control issues.

It would also be fruitful to consider other handheld computer designs, such as PocketPC-based systems, to determine if the present results generalize from the Palm interface to other interface designs. Identification of such usability issues coupled with knowledge of design recommendations based on previous cognitive aging research (see Mayhorn, Rogers, & Fisk, in press) should be informative for device designers.

The present study has shown that at least some portion of the older adult population can learn to use PDAs, and have the potential to reap their benefits as environmental support of prospective memory. Assistive technology has the potential to help older adults to maintain functional independence and maximize their ability to age-in-place (Mynatt & Rogers, 2002). The results described herein have generated multiple design recommendations, and have pointed out several avenues for future research, all aimed at enhancing the number of people that can benefit from this technology.

References

Adler, R. (2002). *The age wave meets the technology wave: Broadband and Older Americans*. Cupertino, CA: SeniorNet.

Allaire, J., & Marsiske, M. (1999). Everyday cognition: Age and intellectual ability correlates. *Psychology and Aging, 14*(4), 627-644.

AmeliaPlex, I. (2003). On-time Rx. Orlando, FL: AmeliaPlex, Inc.

Arslan, S., Atalay, A., & Gokce-Kutsal, Y. (2002). Drug use in older people [Letter to the editor]. *Journal of the American Geriatrics Society, 50*(6), 1163-1164.

Brandimonte, M., & Passolunghi, M. (1994). The effect of cue-familiarity, cue-distinctiveness, and retention interval on prospective remembering. *The Quarterly Journal of Experimental Psychology, 47a*(3), 565-587.

Brown, J. I., Fishco, V. V., & Hanna, G. (1993). *The Nelson-Denny Reading Test*. Chicago: Riverside.

Charness, N., Schumann, C., & Boritz, G. (1992). Training older adults in word processing: Effects of age, training technique, and computer anxiety. *International Journal of Technology and Aging, 5*, 79-105.

Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition*. Hillsdale, NJ: Erlbaum.

Craik, F. I. M., & Rendell, P. G. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology, 14*(Special), S43-S62.

Einstein, G. O., Holland, L. J., Guynn, M. J., & McDaniel, M. A. (1992). Age-related deficits in prospective memory: The influence of task complexity. *Psychology and Aging, 7*(3), 471-478.

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 717-726.

Ekstrom, R. B., French, J. W., & Harman, H. H. (1979). Cognitive factors: Their identification and replication. *Multivariate Behavioral Research Monographs, 79*(2), 84.

Ellis, J. (1996). Prospective memory or the realization of delayed intentions: A conceptual framework for research. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 1-22). Mahwah, NJ: Lawrence Erlbaum Associates.

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology, 47*, 381-391.

Gomez, L. M., Egan, D. E., & Bowers, C. (1986). Learning to use a text editor: some learner characteristics that predict success. *Human-Computer Interaction, 2*, 1-23.

Herrmann, D., Brubaker, B., Yoder, C., Sheets, V., & Tio, A. (1999). Devices that remind. In F. T. Durso, R. S. Nickerson, R. W. Schvaneveldt, S. T. Dumais, D. S. Lindsay & M. T. H. Chi (Eds.), *Handbook of applied cognition*: John Wiley & Sons.

Ivy, G. O., MacLeod, C. M., Petit, T. L., & Markus, E. J. (1992). A physiological framework for perceptual and cognitive changes in aging. In F. I. M. Craik & T.

A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 273-314). Hillsdale, NJ: Lawrence Erlbaum Associates.

Jay, G. M., & Willis, S. L. (1992). Influence of direct computer experience on older adults' attitudes towards computers. *Journal of Gerontology: Psychological Sciences, 47*(4), 250-257.

Kelley, C. L., Morrell, R. W., Park, D. C., & Mayhorn, C. B. (1999). Predictors of electronic bulletin board system use in older adults. *Educational Gerontology, 25*, 19-35.

Kidder, D. P., Park, D. C., Hertzog, C., & Morrell, R. W. (1997). Prospective memory and aging: The effects of working memory and prospective memory task load. *Aging Neuropsychology and Cognition, 4*(2), 93-112.

LaPointe, L. B., & Engle, R. (1990). Simple and complex word spans as a measure of working capacity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 1118-1133.

Leirer, V. O., Morrow, D. G., Tanke, E. D., & Pariante, G. M. (1991). Elders' nonadherence: Its assessment and medication reminding by voice mail. *The Gerontologist, 31*(4), 514-520.

MacDonald, E. T., MacDonald, J. B., & Phoenix, M. (1977). Improving drug compliance after hospital discharge. *British Medical Journal, 2*, 618-621.

Malhotra, S., Karan, R. S., Pandhi, P., & Jain, S. (2001). Drug related medical emergencies in the elderly: Role of adverse drug reactions and non-compliance. *Postgraduate Medical Journal, 77*(913), 703-715.

Marcoulides, G. A. (1991). The relationship between computer anxiety and computer achievement. *Journal of Educational Computing Research, 4*(2), 151-158.

Mayhorn, C. B., Rogers, W. A., & Fisk, A. D. (in press). Designing technology based on cognitive aging principles. In Kwon & Burdick (Eds.), *Gerotechnology: Research and practice in technology and aging*.

Mayhorn, C. B., Stronge, A. J., McLaughlin, A. C., & Rogers, W. A. (2004). Older adults, computer training and the systems approach: a formula for success. *Educational Gerontology, 30*(3), 185-203.

Maylor, E. A. (1996). Does prospective memory decline with age? In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds.), *Prospective memory: Theory and application* (pp. 173-198). Mahwah, NJ: Lawrence Erlbaum Associates.

Melenhorst, A. S., Rogers, W. A., & Caylor, E. C. (2001). *The use of communication technologies by older adults: exploring the benefits from the user's perspective.* Paper presented at the Human Factors and Ergonomics Society 45th Annual Meeting.

Meyer, B. J. F., Talbot, A., Poon, L. W., Puskar, D., & Stubblefield, R. A. (1996). *Task and text factors differentially affect the use of a reading strategy by young and old adults.* Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Moore, A., & Beers, M. (1992). Drug interactions in the elderly. *Hospital Medicine, 117*, 684-689.

Morrell, R. W. (2002). *Older adults, health information, and the World Wide Web.* Mahwah, NJ: Lawrence Erlbaum Associates.

Morrell, R. W., Mayhorn, C. B., & Bennett, J. (2000). A survey of world wide web use in middle-aged and older adults. *Human Factors, 42*, 175-182.

Morrell, R. W., Park, D. C., Mayhorn, C. B., & Kelley, C. L. (2000). The effects of age and instructional format on teaching older adults how to use ELDERCOMM: An electronic bulletin board system. *Educational Gerontology, 26*, 221-236.

Morrell, R. W., Park, D. C., & Poon, L. W. (1990). Effects of labeling techniques on memory and comprehension of prescription information in young and old adults. *Journal of Gerontology: Psychological Sciences, 45*, 166-172.

Morris, J. M. (1994). Computer training needs of older adults. *Educational Gerontology, 20*, 541-555.

Mynatt, E. D., & Rogers, W. A. (2002). Developing technology to support the functional independence of older adults. *Ageing International, 27*, 24-21.

Norman, K. L. (1990). *The psychology of menu selection.* Norwood, NJ: Ablex Publishing.

Park, D. C., Hertzog, C., Kidder, D. P., Morrell, R. W., & Mayhorn, C. B. (1997). The effect of age on event-based and time-based prospective memory. *Psychology and Aging, 12*(2), 314-327.

Park, D. C., & Kidder, D. P. (1996). Prospective memory and medication adherence. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 369-390). Mahwah, NJ: Lawrence Erlbaum Associates.

Park, D. C., Morrell, R. W., Frieske, D., Blackburn, B., & Birchmore, D. (1991). Cognitive factors and the use of over-the-counter medication organizers by arthritis patients. *Human Factors, 33*(1), 57-67.

Park, D. C., Morrell, R. W., Frieske, D., & Kincaid, D. (1992). Medication adherence behaviors in older adults: Effects of external cognitive supports. *Psychology and Aging, 7*(2), 252-256.

Rogers, W. A., Mayhorn, C. B., & Fisk, A. D. (in press). Technology in everyday life for older adults. In Kwon & Burdick (Eds.), *Gerotechnology: Research and practice in technology and aging.*

Salthouse, T. A. (1993). Speed mediation of adult age differences in cognition. *Developmental Psychology, 29*, 722-738.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*(3), 403-428.

Scanlon, T. (1997). *When to develop a wizard*. Retrieved April 20, 2004, from www.uie.com/articles/wizard

Shipley, W. C. (1986). *Shipley Institute for living scale*. Los Angeles: Western Psychological Services.

Sterns, H. L. (1986). Training and retraining adult and older workers. In J. E. Birren & J. Livingston (Eds.), *Age, health, and employment* (pp. 93-113). Englewood Cliffs, NJ: Prentice-Hall.

Tseng, H. M., Tiplady, B., Macleod, H. A., & Wright, P. (1998). Computer anxiety: A comparison of pen-based personal digital assistants, conventional computer and paper assessment of mood and performance. *British Journal of Psychology, 89*, 599-610.

U.S. Census Bureau, P. D., Population Projections Branch. (2000). *National Population Projections*. Retrieved March, 16, 2004, from http://www.census.gov/population/www/projections/natsum-T3.html

Vicente, K. J., Hayes, B. C., & Williges, R. C. (1987). Assaying and isolating individual differences in searching a hierarchical file system. *Human Factors, 29*(3), 349-359.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale III (3rd Ed.)*. San Antonio, TX: The Psychological Corporation.

Worden, A., Walker, N., Bharat, K., & Hudson, S. (1997). Making Computers Easier for Older Adults to Use: Area Cursors and Sticky Icons. *Proceedings of the CHI '97 Conference on Human Factors in Computing Systems*, 266-271.

Wright, P., Bartram, C., Rogers, N., Emslie, H., Evans, J., Wilson, B., et al. (2000). Text entry on handheld computers by older users. *Ergonomics, 43*(6), 702-716.

Zola, I. K. (1986). Thoughts on improving compliance in elderly arthritics. *Geriatrics, 41*(8), 81-85.

Appendix A: Task Analysis of On-Time Rx PDA Software

	Tasks	Required Knowledge	Potential Errors
			Note: all tasks have the potential for motor control errors. Most targets are quite small. Therefore, only in exceptional instances will motor control errors be specified. MC = Motor Control Error COG = Cognitive Error
1	Begin entering medication information	How to begin	COG may not understand where to begin
1.1	Tap MyMeds	Empty list indicated no medications are entered	COG may not understand where to begin
1.2	Tap New	New medication is entered here	COG may not understand where to begin
1.2.1	Enter drug name and strength by tapping on-screen keyboard	Tap to type; SP is space	MC many small "keys"; COG Space key not evident; COG Space key not evident
1.2.1.1	Tap Done when finished	Done is where Enter key usually is	COG Done is key not button as it is everywhere else
2	To input frequency of doses tap down arrow next to 1dose/day	Frequency of Doses; There is a drop-down list	COG there are many down arrows on screen; MC arrow is very small
2.1	Tap 2X/day	Know correct number of doses	MC drop down entries are very compact; COG there is no definite exit from the task--no Done to tap
3	To input scheduling information Tap Not Set	Schedule information; That Not Set is how to open schedule editor	COG no visible control, no intuitive way to know where to tap, not consistent with other fields

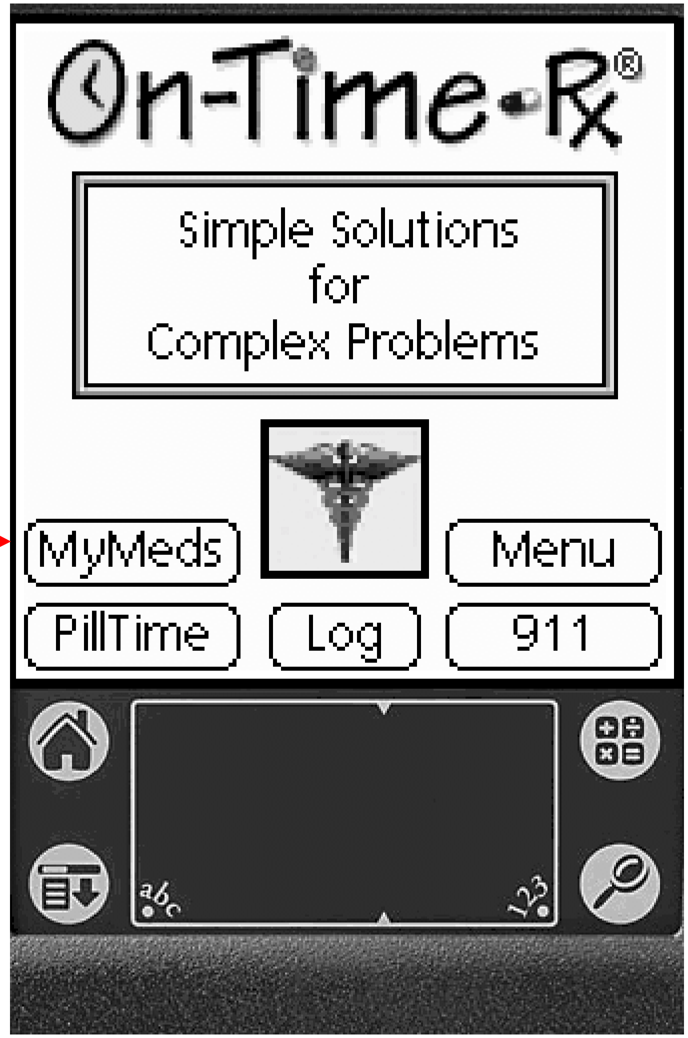
3.1	Tap 8:00am	Tapping on the time is how to open time editor	COG no visible control, no intuitive way to know where to tap, not consistent with other fields
3.1.1	Tap Up Arrow to change time to 9:00 AM	Arrow controls time digits; highlighted digit is the one being edited; digits are independent	MC small arrow; COG may hit wrong arrow and scroll time in wrong direction; COG may try to tap digit to edit; COG may try to change AM or PM
3.1.2	Tap OK when finished	OK exits time editor	COG may think that OK exits Scheduling sub-task
3.2	Tap 8:00pm	Tapping on the time is how to open time editor	COG no visible control, no intuitive way to know where to tap, not consistent with other fields
3.2.1	Tap Down Arrow to change time to 6:00 PM	Arrow controls time digits; highlighted digit is the one being edited; digits are independent	MC small arrow; COG may hit wrong arrow and scroll time in wrong direction; COG may try to tap digit to edit; COG may try to change AM or PM
3.2.2	Tap OK when finished	OK exits time editor	COG may think that OK exits Scheduling sub-task
3.3	To set repeat information tap None	Is schedule daily, weekly, monthly; None is control for opening Repeat editor	COG no visible control, no intuitive way to know where to tap, not consistent with other fields; COG may not understand "repeat" function and may omit step; COG may try to change End Date
3.3.1	Tap Day	Tap daily tab to change to daily schedule editor	COG may not equate Day to daily; COG may try to change "every 1 day"
3.3.2	Tap OK when finished	Task is finished; OK exits	COG may think that OK exits Scheduling sub-task
3.4	Tap Done	Task is complete	May think Done exits New Med task
4	To input where to administer tap down arrow next to In:	There is a drop-down list	COG complex and confusing screen may draw attention; COG many arrows; MC small arrows

4.1	Tap down arrow to scroll drop-down list	That list scrolls	COG may not realize down arrow scrolls list; MC very small arrow
4.1.1	Tap Mouth	Administration location	COG if above step not completed; MC drop down entries are very compact; COG there is no definite exit from the task--no Done to tap
5	To input how to take tap down arrow next to With:	There is a drop-down list	COG complex and confusing screen may draw attention; COG many arrows; MC small arrows
5.1	Tap Milk	Taken with Milk	MC drop down entries are very compact; COG there is no definite exit from the task--no Done to tap
6	To input why it is taken tap down arrow next to For:	There is a drop-down list	COG complex and confusing screen may draw attention; COG many arrows; MC small arrows
6.1	Tap down arrow to scroll drop-down list	That list scrolls	COG may not realize down arrow scrolls list; MC very small arrow
6.1.1	Tap Allergies	Treated condition	COG if above step not completed; MC drop down entries are very compact; COG there is no definite exit from the task--no Done to tap
7	Tap Done	Done exits subtask	COG complex and confusing screen may draw attention; COG many buttons
8	Medication appears in MyMeds list. Tap Done	That task is finished	COG instructions call for Done to be tapped in back-to-back steps
9	To verify schedule tap Pill Time. Note errors and report them	What the schedule should look like	COG may not catch errors; COG may try to correct errors
9.1	Tap Done	Task is finished	COG several buttons may compete for attention

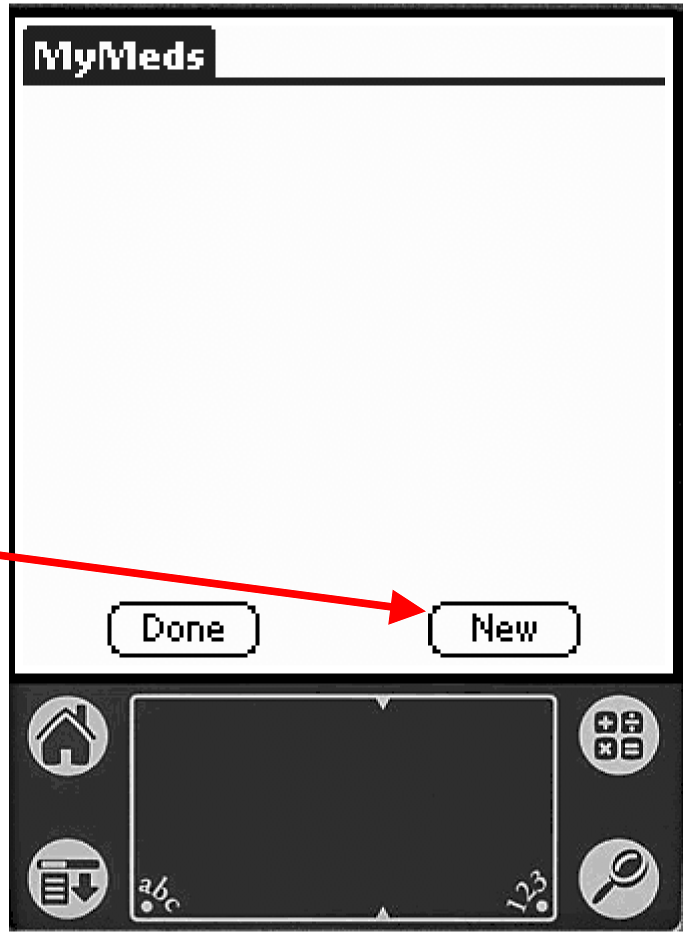
Appendix B: Training Manual

Your friend, Pat, has just returned from the doctor with a new prescription. Pat is very forgetful. Pat bought a handheld computer and believes it will help organize all the prescription information.
Pat asks you to enter the medication information.
This is the instruction manual for entering a new prescription.

Tap **MyMeds** to begin.



This is the main screen for the On-Time Rx program. Please pay close attention to these instructions as you will have to perform these tasks again later, without instruction. You will now begin the process of entering **fictitious** medication information into the program.



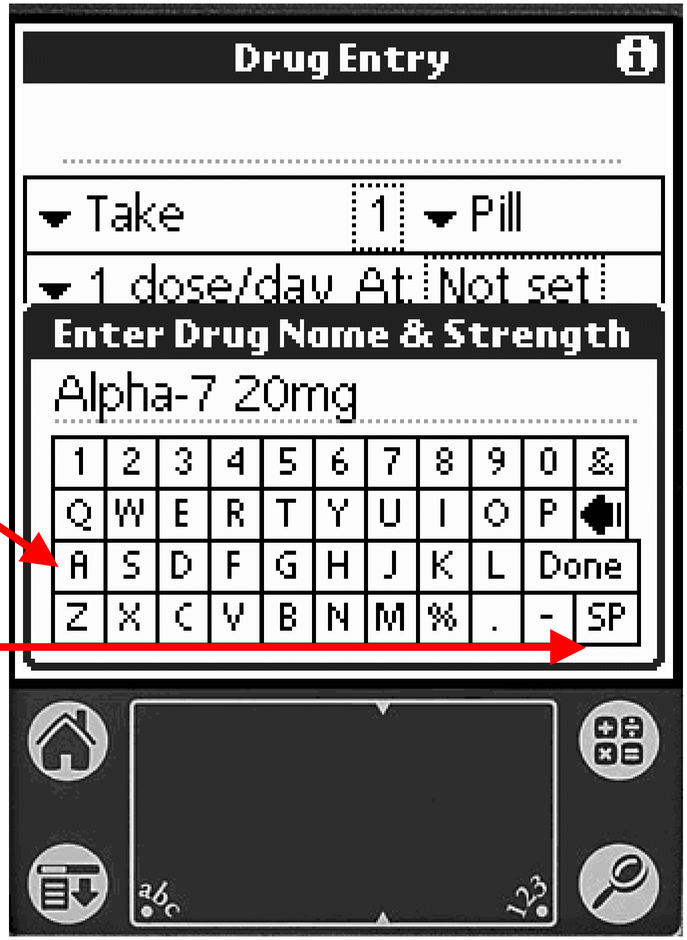
Tap
NEW
to begin.

This screen displays any medications entered in the program (the list will be empty until you have entered the medication).
When the task is complete the medication will be displayed here.

Tap the appropriate letters to spell **Alpha-7**.

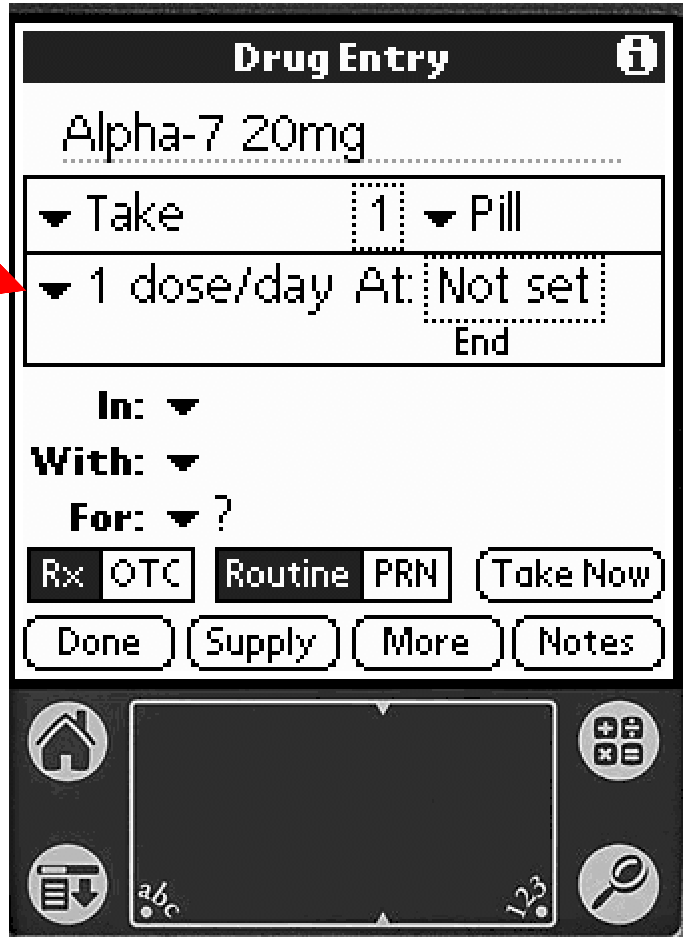
For a space tap **SP**.

Tap the appropriate letters to spell **20mg** and then tap **Done**.



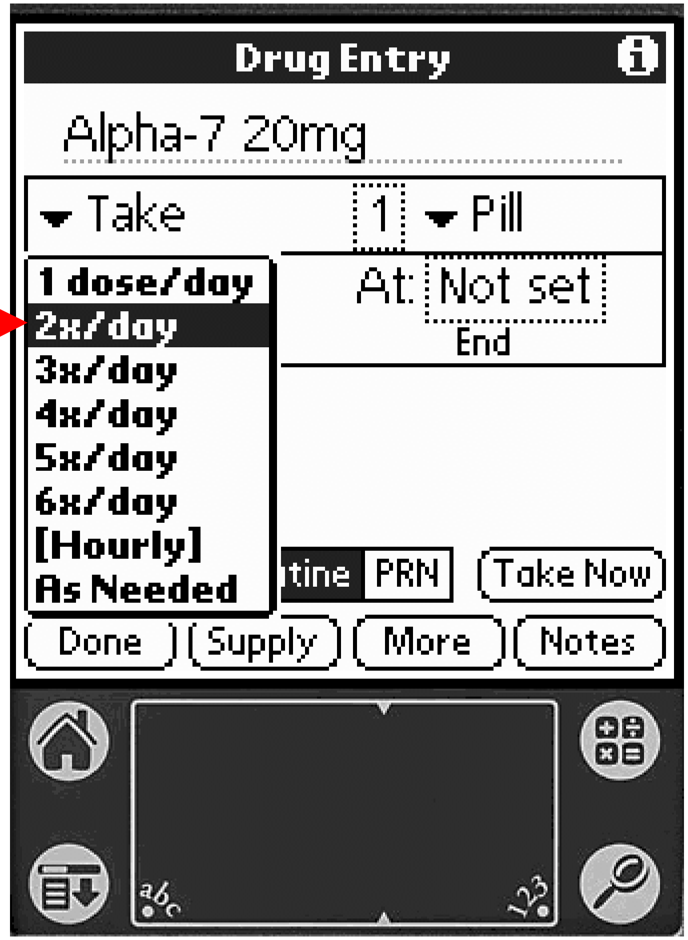
This screen is where you will enter the medication name and strength.
The medication is **Alpha-7** and its strength is **20mg**.
The on-screen keyboard allows you to tap in the information.

Tap the ▼ **down arrow** to see other options.

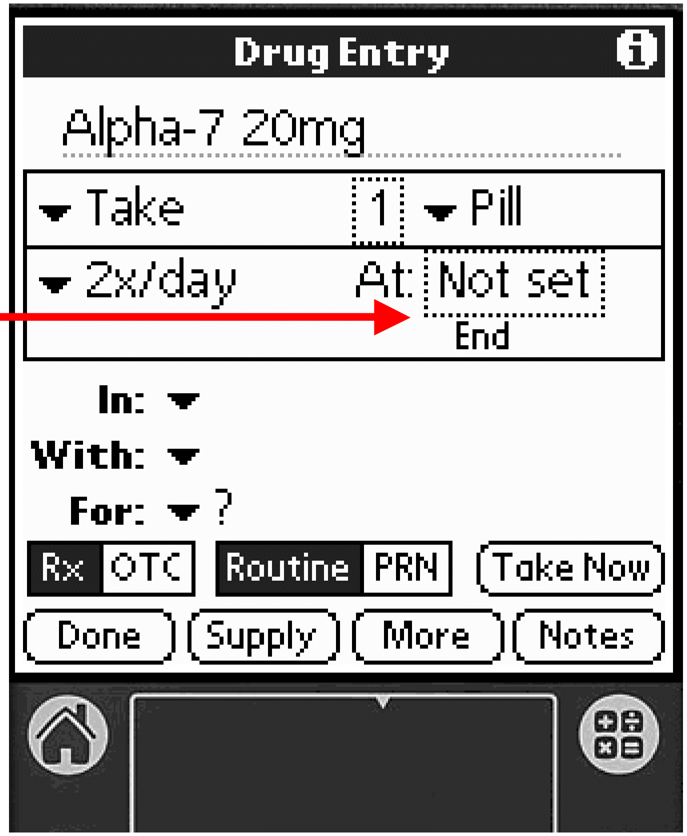


This screen is where you will enter the details about the medication.
Alpha-7 is taken twice a day.

Tap **2x/day**.



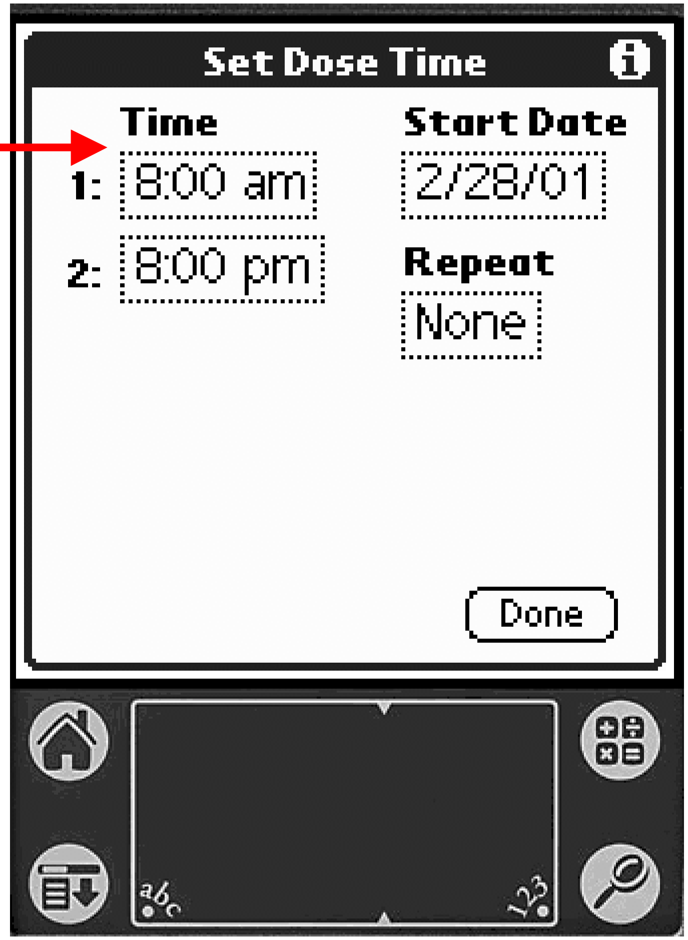
This screen is where you will choose the option for twice a day.
Alpha-7 is taken twice a day.



Tap **Not set**.

The screen now shows that **Alpha-7** is taken twice a day. You will now set the times of day it should be taken.

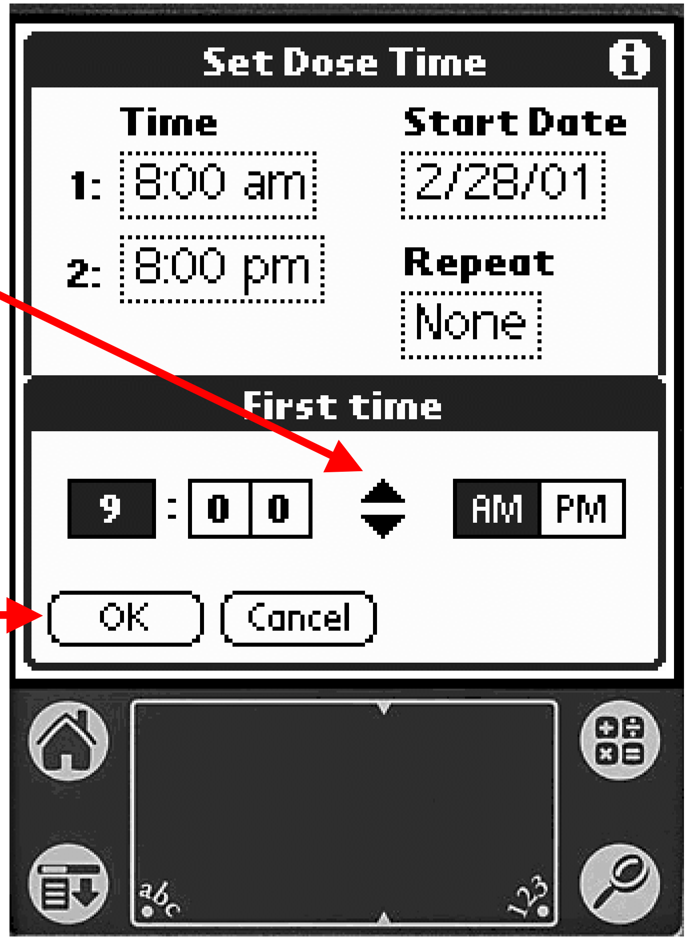
Tap **8:00 am**.



The screen now shows the current schedule. It is incorrect. You will now change the first time.

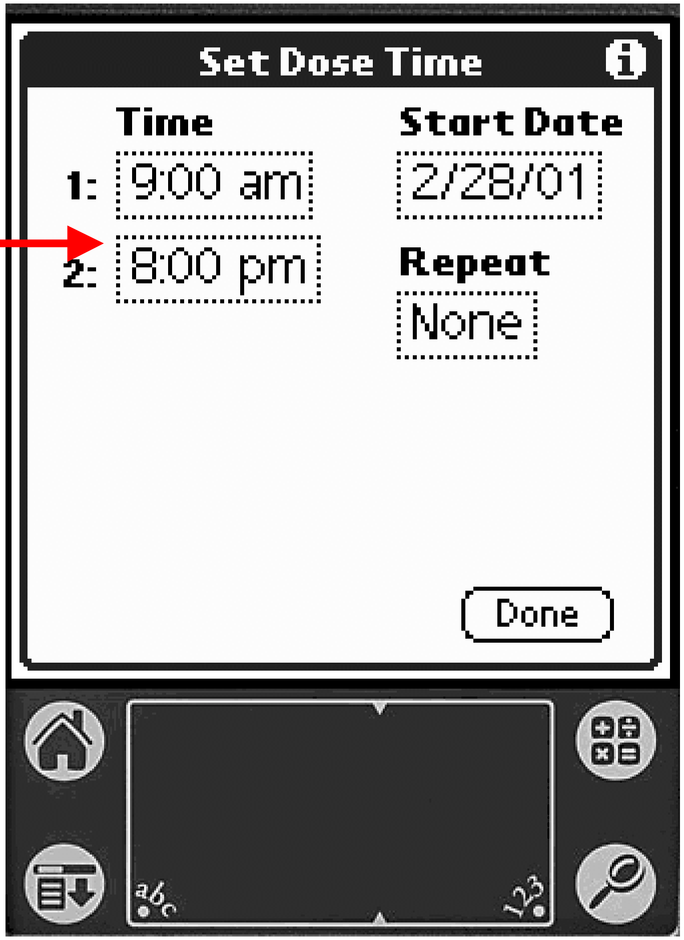
Tap the ▲ **up arrow** to change the time to 9:00 am.

Tap **OK** when you are finished.



This screen is where you will change the time.
The correct time for the first dose is 9:00am.

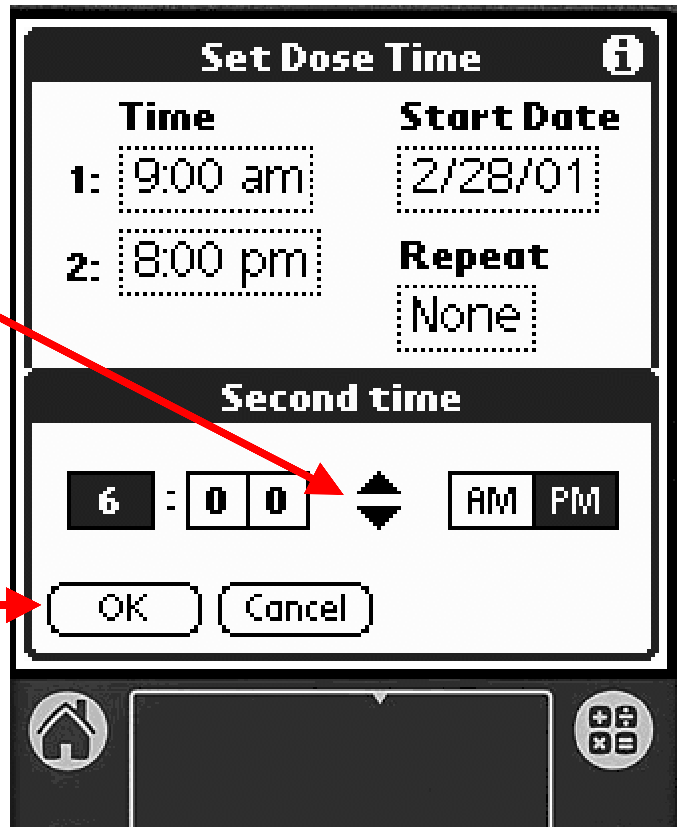
Tap **8:00 pm**.



This screen now shows the first dose you just entered as 9:00 am.
The second time is incorrect. The correct time for the second dose is 6:00 pm.

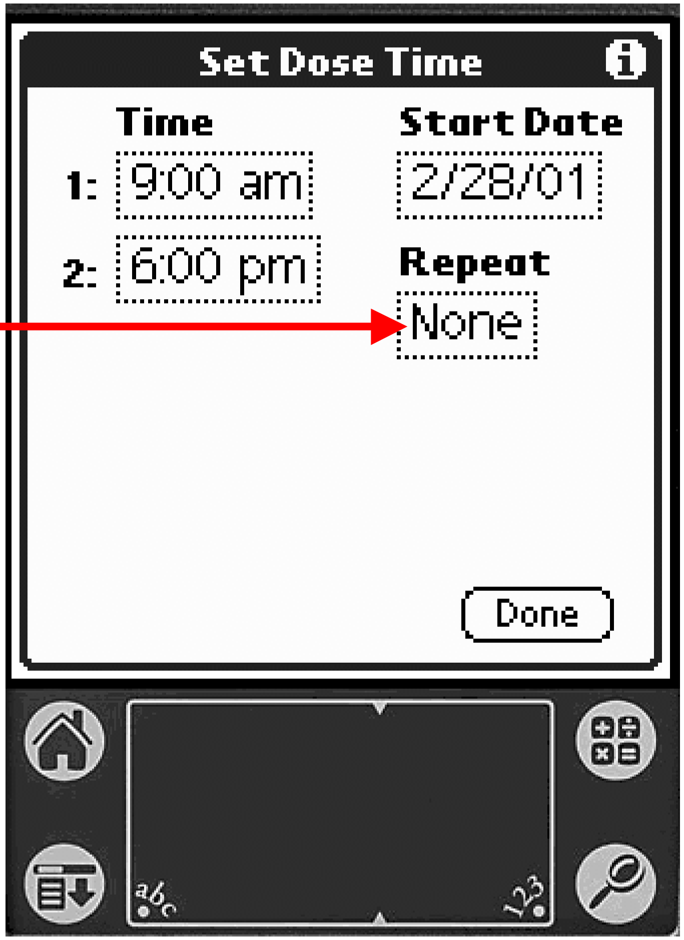
Tap the ▼ **down arrow** to change the time to 6:00 pm.

Tap **OK** when you are finished.



This screen is where you will change the time.
The correct time for the second dose is 6:00 pm.

Tap **None**.



The screen now shows the doses are taken at 9:00 am and 6:00 pm.
You will now change how often the schedule repeats.

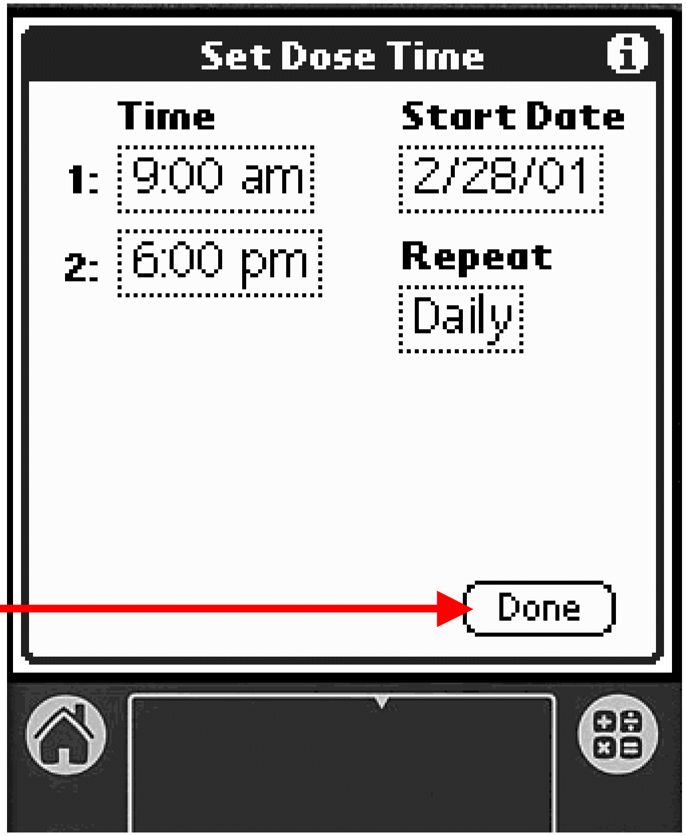
Tap **Day**.

The screen currently shows the schedule does not repeat.
This is incorrect.
Alpha-7 is taken daily.

The screen now shows the schedule repeats daily. No other changes are necessary here.

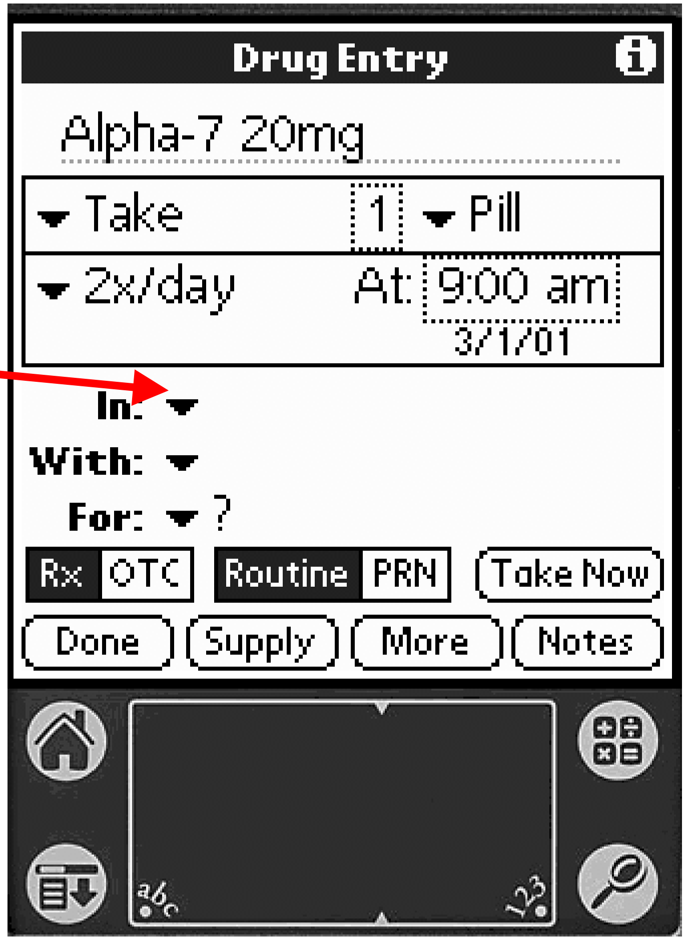
Tap **OK**.

Tap **Done**.

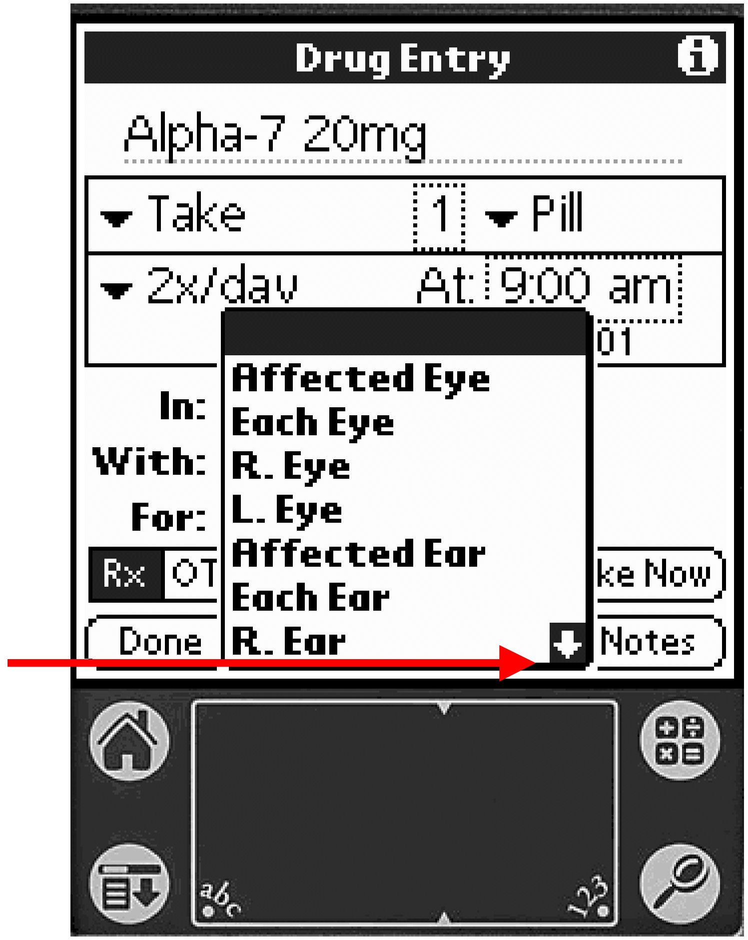


The screen now shows the doses are taken at 9:00 am and 6:00 pm and this is repeated daily.
The program is now set to sound alarms at the appropriate times.
You have entered all the time information for the **fictitious** medication.

Tap the ▼ **arrow** next to **In:** to see other options.



The screen now shows **Alpha-7** is taken 2x a day and the next dose is due at 9:00 am.
The medication is taken orally.
You will now enter this in the program.

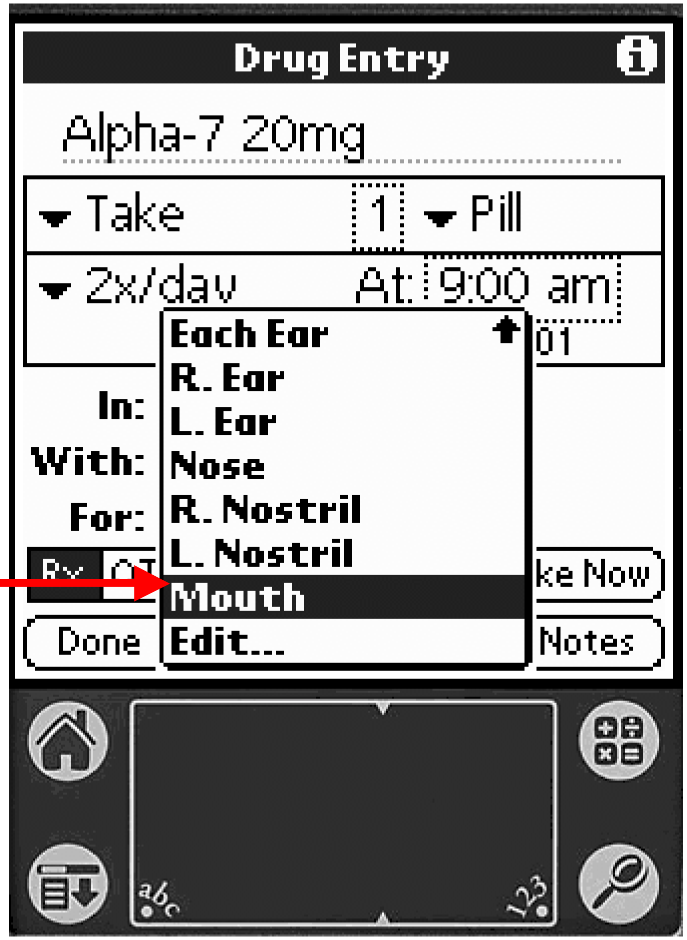


The medication is taken orally. Mouth is further down the list.

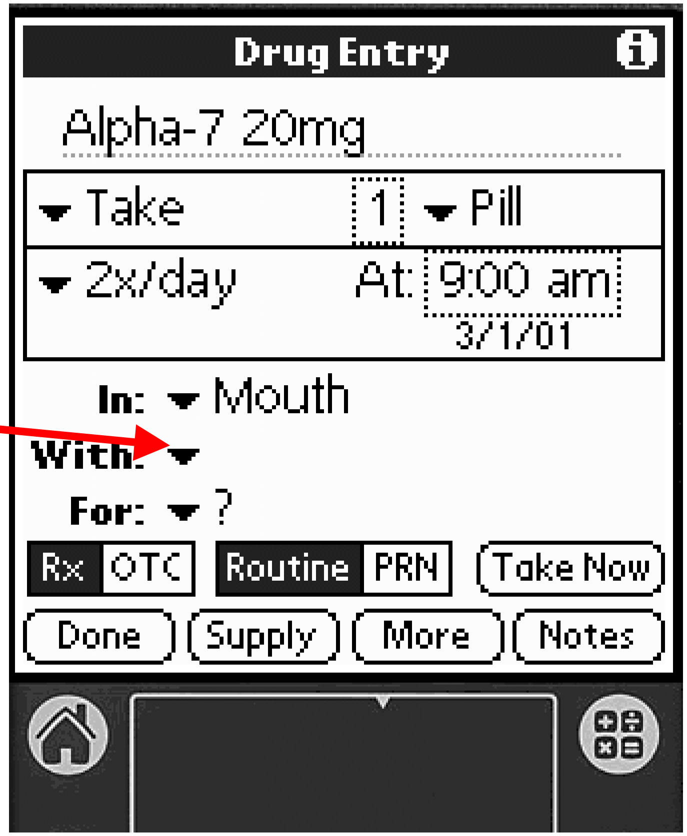
Tap the ⬇ **arrow** one time to see more options.

The medication is taken orally.
You will now select **Mouth**.

Tap **Mouth**.



Tap the ▼ **arrow** next to **With:** to see other options.

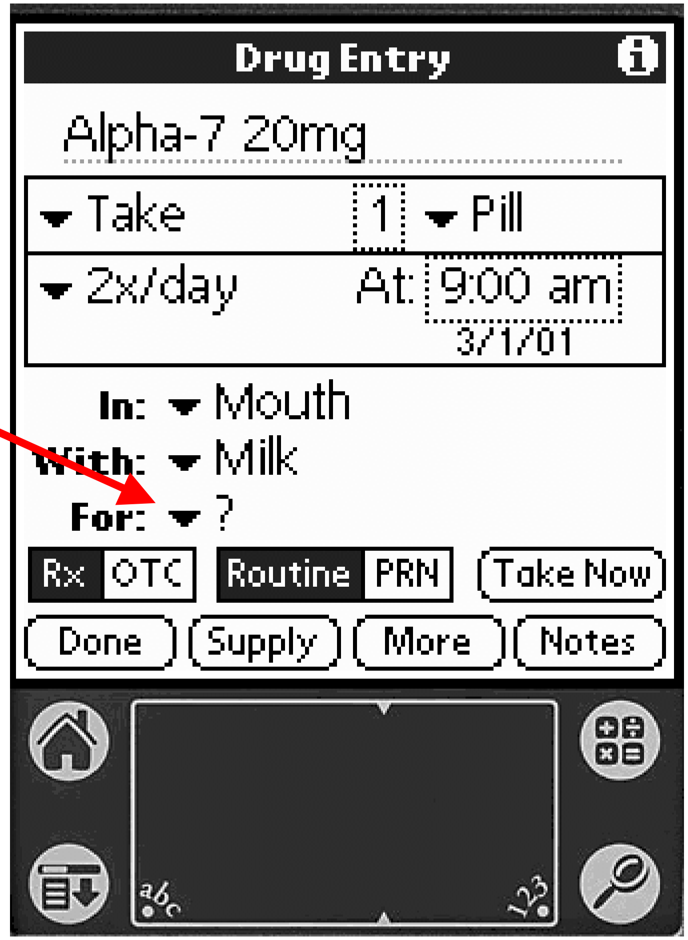


You have indicated the medication is taken orally. **Alpha-7** is taken with milk.

Tap **Milk**.

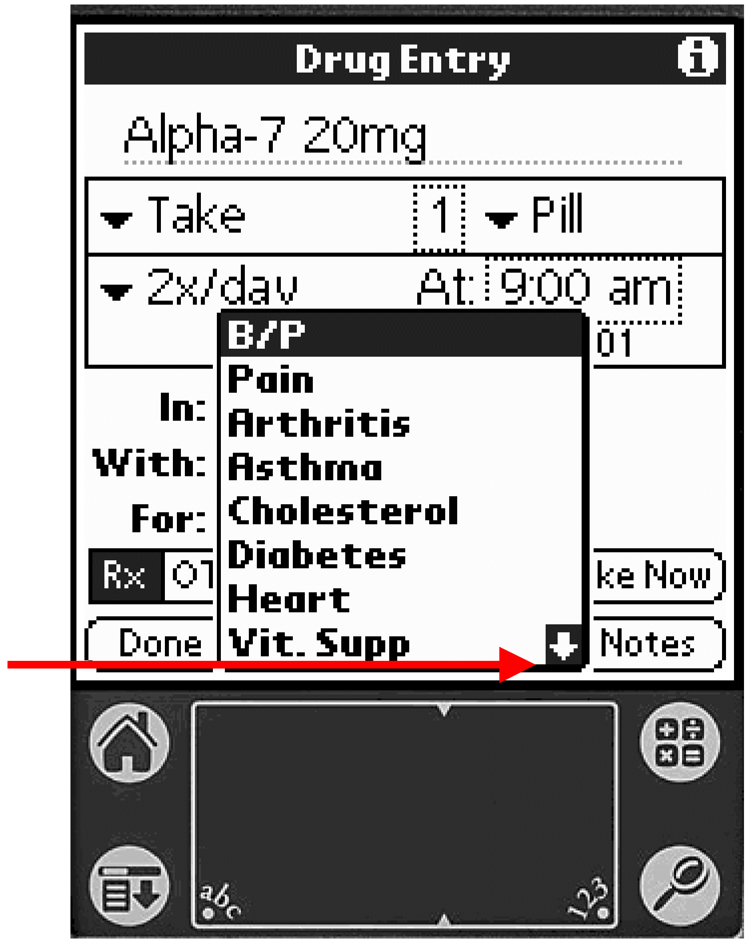
You will indicate that the medication is to be taken with milk.

Tap the ▼ **arrow** next to **For:** to see other options.

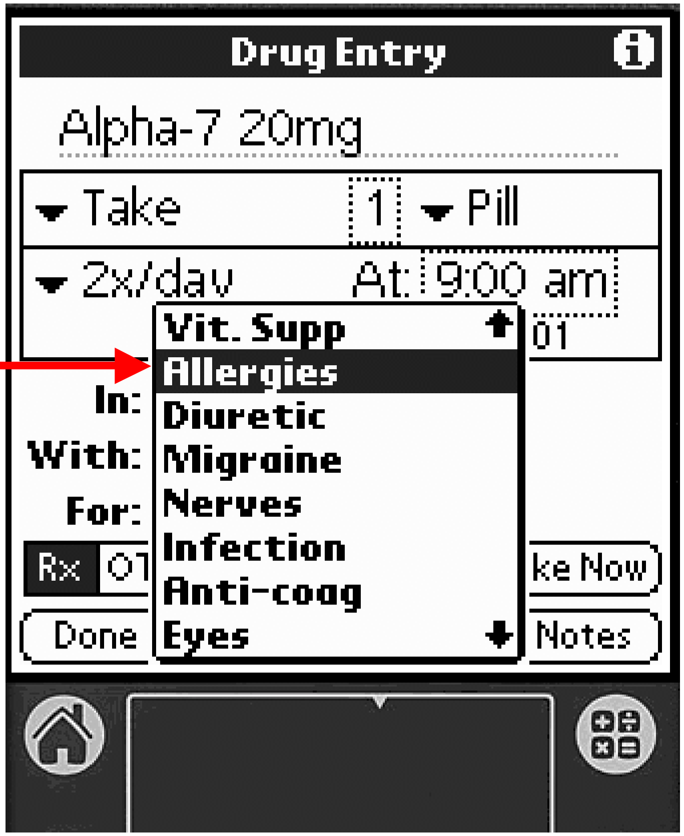


You have indicated the medication is to be taken with milk.
Alpha-7 is taken for allergies.

The medication is taken for allergies.
Allergies is further down the list.

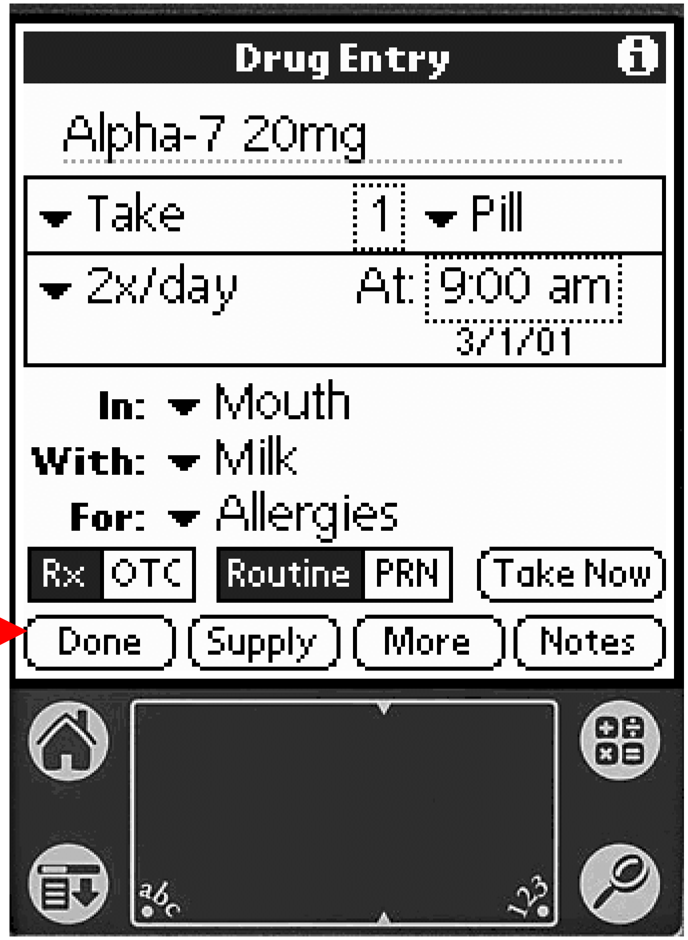


Tap the ⬇ **arrow** one time to see more options.



Tap **Allergies**.

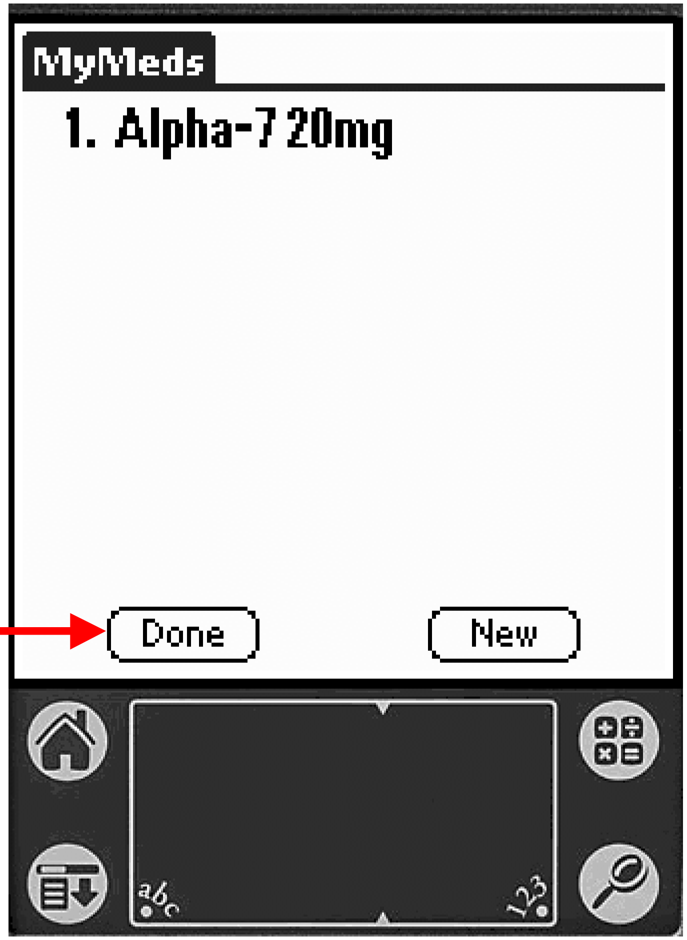
You will indicate that the medication is taken for allergies.



Tap **Done**.

You have indicated the medication is to be taken orally, with milk, and for allergies.
You have entered all the necessary information for **Alpha-7**.

Tap **Done**.

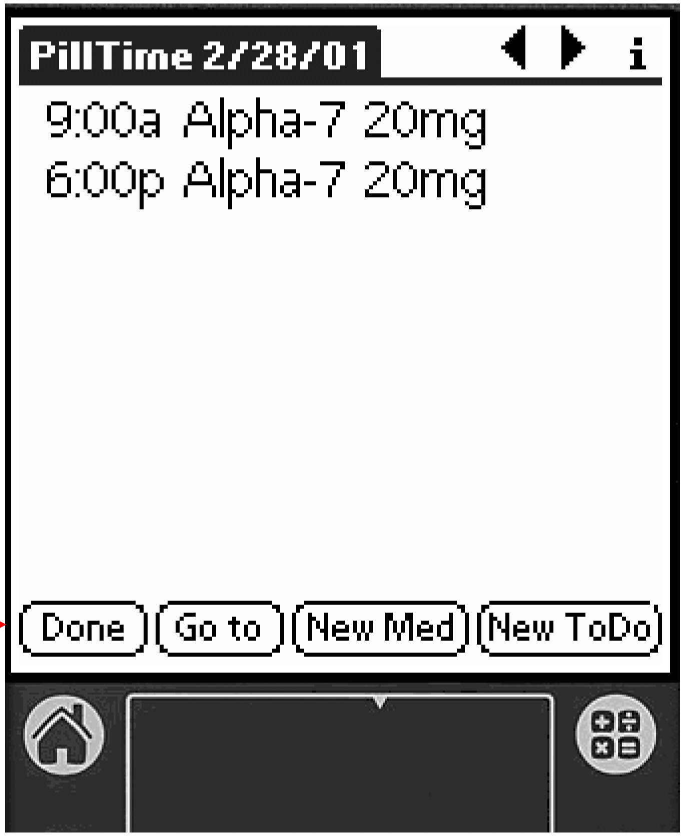


This screen displays any medications entered in the program. The list now includes the **fictitious** medication you just entered.

You are finished entering the medication.

Tap **PillTime**.

You will now verify that the schedule for the **fictitious** medication you just entered is correct.



Tap **Done**.

Verify that the information for **Alpha-7** is correct.
The schedule should show **Alpha-7** being taken at 9:00 am and 6:00 pm.
Please tell the experimenter if the schedule is correct.

You are now finished setting up the medication schedule.

Appendix C: Medication Information

Pat was given a second medication by the doctor. Please enter the information below for this new medication.

The medication name is **Beta-8 5mg**

Take **3 times a day**

Take at **6:00 AM, 1:00 PM, and 9:00 PM**

Repeat schedule **daily**

Take in **mouth**

Take with **water**

Take for **nerves**

Please check to see if the schedule is entered correctly.

Pat was given a third medication by the doctor. Please enter the information below for this new medication.

The medication name is **Gamma-9 125mg**

Take **once per day**

Take at **7:00 AM**

Repeat schedule **daily**

Take in **mouth**

Do **not** take with **food**

Take for **cholesterol**

Please check to see if the schedule is entered correctly.