Advances in handheld computer technology are making data collection faster, easier, and more accurate. In this article, the use of personal digital assistants (PDAs) to collect data for a study on elder neglect is described and evaluated. Methods for integrating this technology into a research study are discussed as are suggestions for increasing the performance of data collectors using these devices. The authors offer some practical solutions for researchers and clinicians planning to use PDAs in their research.

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THE PURPOSE OF this article is to describe how handheld computers (also referred to as personal digital assistants [PDAs]) have been used to collect data in emergency departments (EDs) for a multisite study on elder neglect and to comment on the advantages and disadvantages of using PDAs for patient data collection on this project. From this experience, a number of recommendations for researchers considering the use of PDAs for data collection are offered.

BACKGROUND

In recent years, the use of handheld computer PDAs has risen tremendously in the health care field (Sausser, 2002; Shah, 2001). These units have been used to enter patient information and track patients during direct and point of service care, as reference tools and to make medical calculations. In health care systems where PDAs are connected to information systems, clinicians may use the devices to check laboratory results or write prescriptions. The devices have also been used for general data collection, particularly in the case of survey research or health assessment (Burnard, 1995; Craig, 2002; Sausser, 2002). In the case of data collection for research, PDAs can replace paper-based instruments that are usually coded and entered into statistical or spreadsheet software after the initial data has been collected. By contrast, researchers can use software for handheld devices that codes and saves data into a form that can be imported directly into databases or statistical packages at the time of data collection. Data can be entered into the PDA and then transferred or “synchronized” to a desktop computer by a variety of means, depending on the needs and restrictions of the project. Such means typically include a telephone or Internet through the use of a modem, an infrared connection, a docking station, or a hard-
wire cable (Craig, 2002; Weber, Roberts, & Beverly, 2000).

**ADVANTAGES AND DISADVANTAGES**

The use of PDAs to collect data has several distinct advantages in comparison to traditional paper and data entry collection techniques. These advantages include decreased errors, increased efficiency of data entry, quick access to patient information, and the portability of the devices (Van Dinter, 2002). Ease of storage, reduction of response errors through a variety of programming methods, and the fact that a single device can be used for many different respondents have also been cited as main advantages of PDAs (McBride, Anderson, & Bahnsen, 1999). Among the disadvantages are the possibility of losing data if the device breaks, the potential for staff discomfort with the technology and the need for special training, the existence of occasional compatibility problems, and the potential for users to get inadvertently locked out of the devices depending on the security mechanisms in place. Finally, the rapid pace of new handheld technologies may cause the device and/or software to become outdated during the life of the project (Sausser, 2002). The use of PDAs to collect data has several distinct advantages in comparison to traditional paper and data entry collection techniques.

**RELIABILITY OF DATA COLLECTED USING PDAS**

Some researchers have found that collecting data with handheld devices yields similar results to pen and paper methods. In a randomized study, McBride et al. (1999) compared pen and paper survey methods to handheld computer methods for data collection in an orthopedic outpatient clinic. The authors found that data collection by handheld computers was comparable to that by pen and paper, with no statistically significant mean difference in the scale scores between the handheld and paper versions of the survey. However, use of the handheld devices was shown to have less internal reliability than pen and paper surveys. In a controlled experiment, Young et al. (2001) studied the utility and efficiency of pen-based handheld devices compared with keyboard based devices for data collection by nurses. Three nursing-record simulation tasks were undertaken representing (1) structured data entry (selecting items from a pull down list), (2) structured and textual data entry, and (3) solely textual data entry, respectively. Nurses in the study reported that the pen-based device was preferred for accuracy and ease over the keyboard for tasks 1 and 2, but for task 3, the keyboard was preferred. The authors postulate that choosing to use a pen-based device or a keyboard-based device to collect data should depend on the data input method of the software being used. Some researchers have found that collecting data with handheld devices yields similar results to pen and paper methods.

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As handheld technology becomes more sophisticated, user friendly, and cost-effective, the use of PDAs to collect data will be most likely increase. In this process of adapting technology to aid in research, it is important for researchers understand the reliability of using the technology to collect data compared with pen and paper methods and the steps that can be taken in programming PDAs to aid in the collection of reliable data.

**STUDY DESCRIPTION**

As part of an ongoing, multisite study on elder neglect by caregivers, PDAs have been used to collect patient data in 4 EDs: 2 in New York City and 2 in Tampa, FL, from March 2001 to May 2003 (Fulmer, Paveza, Abraham, & Fairchild, 2000). As part of the protocol, eligible patients who agreed to participate and sign informed consent were interviewed and assessed for neglect by clinical screeners using the Elder Assessment In-
The Elder Assessment Instruments (EAI) (Fulmer, Street, & Carr, 1984; Fulmer & Wetle, 1986, Fulmer, Paveza, Abraham, & Fairchild, 2000). The EAI (Fig 1), a 44-item Likert scale assessment instrument was developed to measure possible neglect over 7 subcategories: general assessment, neglect assessment, usual lifestyle, social assessment, medical assessment, emotional/psychological neglect, and a summary assessment. Response choices for these items range from “very good” to “very poor” or “no evidence” to “evidence.” A disposition section provides an area for notes regarding the follow-up plan for the patient. The interrater reliability for this instrument is .83, and the content validity is .83 (Fulmer, Street, & Carr, 1984; Fulmer & Wetle, 1986). This instrument along with basic demographic variables and questions to assess eligibility requirements were the basis for a Palm Pilot (Palm, Inc, Santa Clara, CA) (now called PalmOne)–guided interview, which was programmed and installed onto the handheld devices and used by screeners to assess for elder neglect in the EDs.

Screeners for the study were trained in the use of the Palm Pilot, EAI, and American Medical Association’s “Diagnostic and Treatment Guidelines for Elder Abuse and Neglect” (Aravanis, Adelman, Breckman, Fulmer, Holder, & Lachs, 1992) over a 6-hour training session. Screeners assessed patients and used the data gathered from the EAI to formulate a subjective clinical judgment of neglect or no neglect. Data collected were cued and entered into Palm Pilots and forwarded to a database housed on a remote server as well as to the Neglect Assessment Team (NAT) for review. An interdisciplinary NAT, consisting of a geriatrician, geriatric nurse practitioner, and social worker with expertise in elder mistreatment, received data from the ED screens weekly and reviewed the cases to confirm or disconfirm the original diagnosis.

**TECHNICAL DESCRIPTION**

The main goals for the technical implementation of the Palm application were (1) to provide an easy

![Figure 1. Elder Assessment Instruments (EAI).](image-url)
to understand Palm-based data collection program to maximize efficiency in the ED, (2) to minimize training needs of data collectors, and (3) to ensure secure data transfer to a central server using a common phone hookup.

The Palm Pilot Platform was chosen for its cost-effective hardware and solid industry support for end users as well as software developers. The project used Palm III models and later M125 models that were outfitted with a modem. On startup, the Palm software for this study provided 4 selections for the ED screeners (Fig 2): (1) enter a new case, (2) review an existing case, (3) upload all cases to the central server, (4) and delete all cases from the PDA (without clearing cases from the server).

Entering or reviewing cases occurred through simple on-screen forms with minimal handwriting. Because the Palm Pilot screens are small, the challenge of collecting 143 variables was met by spreading them over multiple individual screens. On data entry (or review), the software provided defaults for certain variables (i.e., inserting the current date in the “today’s date” question block), provided “roadblocks” for incomplete data entry (screens would not change to the next without all information present), and validated the entry to prevent invalid data (i.e., the response falls outside of expected parameters, please correct the response to continue). Once the first few forms, containing eligibility criteria variables were completed, the software registered whether the subject was eligible for the study. This study used the Mini Mental Status Examination (Folstein, Folstein, & McHugh, 1975) to determine if the subject had the appropriate cognitive capacity to participate. Calculation of the Mini Mental Status Examination score was registered automatically by the Palm software (Fig 3).

A technical consultant company with expertise in research and software development programmed the application and provided technical support for the implementation phase. The server was connected by modem to a telephone line and waited for the handheld devices to call and send data. To upload data, the Palm dialed a nationwide toll-free number and authenticated the connection and security by username/password within the Windows NT (Microsoft, Irving, CA) and Palm server procedures. Once connected, the data were transferred to the server using transmission control protocol/Internet protocol (the suite of communications protocols used to connect hosts on the Internet) and encryption, which is the translation of data into a secret code. Use of encrypted data help to keep data secure because a special password is needed to decrypt data in order to read them.

After the server confirmed a successful upload of data, assessment clinicians were advised to remove all cases from the Palm memory for additional security and upload performance. Upload of data took several minutes, depending on the number of cases. In this study, the server was located in a third-party contract research company and was dedicated to this study alone to avoid any security breaches. The server database was backed up periodically.

**THE HANDHELD EXPERIENCE**

All screeners were provided with a Palm Pilot handheld device with the ED screening tool application installed. Staff training took place over the course of three 2-hour meetings, and it included practicing the use of the stylus and the Graffiti function on the Palm, entering and uploading test cases, and measuring interrater reliability based on 3 cases studies (Table 1). The interrater reliability coefficient for the assessment personnel for each of the 3 cases was .96 (Kendall coefficient of concordance).

During training, screeners initially had little or no trouble acclimating to using the Palm to enter data and had mastered using the stylus very quickly; however, once screeners began to work in the busy clinical setting of the EDs, it became more difficult for them to manage both patient interaction and...
electronic data collection simultaneously. It was cumbersome to focus on the handheld device and the patient, in particular, while entering the variables that required using the Graffiti function to with the stylus or the typing of long strings of characters via the PDA screen keyboard. The

Table 1. Training Plan Outline: Dyadic Vulnerability/Risk Profiling for Elder Neglect

<table>
<thead>
<tr>
<th>Phase one: introduction</th>
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<tbody>
<tr>
<td>General Meeting of all staff with principal investigators and project managers</td>
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<tr>
<td>Highlight the issues surrounding and need for elder mistreatment research</td>
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<tr>
<td>Study overview, including timeline for all aspects of data collection</td>
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<th>Phase two: familiarity</th>
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<tr>
<td>Screeners at both sites participate in training around the specific instruments used and the palm technology they will use to collect them</td>
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<tr>
<td>Education of the instruments: education provided re: each instrument’s need for inclusion, method of administration &amp; recognition of appropriate response coding</td>
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<tr>
<td>Palm Pilot technology: basic operation of the Palm including parts of the screen, stylus, drop down menus, on-screen keyboard, and Graffiti writing</td>
</tr>
<tr>
<td>Palm-based instruments: the integration of instruments and PDA technology</td>
</tr>
<tr>
<td>Practice: Role playing between staff screeners in the both the role of screener and patient</td>
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<tr>
<td>Verification: Screeners administered test cases uploaded and analyzed for interrater reliability</td>
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<th>Phase three: implementation</th>
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<tr>
<td>Screeners at both sites begin ED data collection</td>
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<td>Screeners supervised by senior grant staff for 2 initial days of data collection</td>
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<tr>
<td>Screeners subject to weekly review by senior grant staff for a period of 1 month</td>
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<th>Phase four: verification</th>
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<tr>
<td>Project managers at both sites ensure data collected and uploaded in error free manner</td>
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<tr>
<td>In field: screeners subject to periodic monthly review by senior grant staff</td>
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<tr>
<td>Screeners upload cases to central data base</td>
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<tr>
<td>Project Managers verify all cases collected are uploaded and verified on weekly report</td>
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screeners found entering the variables in a drop-down list, where choices were tapped, more manageable. As a result, many of the screeners began to screen the patients for neglect using a pen and paper version of the screening instrument and later enter these data into the handheld devices during slower periods when fewer patients were available for screening. To counter this, the screeners were provided with portable keyboards that could be attached to the devices to make it easier to type textual data, yet, the preference for pen and paper screening persisted. All of the screeners collected data on paper initially, and later entered their data to the Palm for uploading to the NAT and the server. All of the screeners collected data on paper initially and later entered their data to the Palm for uploading to the NAT and the server.

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#### Uploading

As mentioned, transfer of data from the handheld devices to a desktop-based statistical database was conducted using modems and a telephone line to upload. Data from the two New York sites were uploaded weekly, whereas those from the Florida sites were uploaded on a daily basis. An automated report with the names and contact information of all of the newly enrolled patients from the four clinical sites was then issued to the project managers in New York and Florida on a weekly basis. The project managers would review the report for confirmation that all the cases enrolled were received in the database. An additional report of the new enrollees and their data from the ED screening instrument was sent to the NAT in order for them to review each case and make a determination regarding confirmation of diagnosis. Patient names and identifiers were removed from these NAT reports for the sake of eliminating bias and to protect the privacy and confidentiality of study subjects.

Although the uploading process via modem for transfer of data had been quick and easy for the most part, there have been six times over the course of the study, when failures with the server caused the devices to not connect and upload properly. In each of these cases, it took between 1 and 2 weeks to correct the server difficulties, during which time data were collected on paper and later input into the Palm when they were successfully uploading again. In addition, uploading was initially hindered by the fact that it often took several “dial-ups” to connect the devices to the server. It was later found that once data were uploaded and then deleted from the devices on a regular basis, uploading occurred with little problems and was more successful.

#### Equipment Loss and Security

Over the course of the study, one of the handheld devices was lost and two were broken or malfunctioned. Although password protected, the lost Palm was reported as an adverse event to the institutional review board. The security of patient data is always a concern, particularly in light of the newly enacted privacy provisions of the Health Insurance Portability and Accountability Act of 1996 (Morrison, 2002). As a result, special precautions have been taken during the study to insure that subjects’ private health information is protected. These measures include password protecting the handheld devices, locking them up when not in the ED, encrypted data transmissions, and restricted network and database access. Random ID numbers and deidentified data were used to keep a denominator count of those patients who are not enrolled in the study and do not sign consent and/or Health Insurance Portability and Accountability Act authorization.

Battery failure was also a source of data loss for the project. Although the data collected were backed up with hard copies, the data collection programs installed on the Palm would delete themselves after 30 minutes of battery loss time. Once fresh batteries were installed, the programs were still unrecoverable and needed to be fully reprogrammed. To avoid this, it was necessary to mandate a standardized monthly changing of all Palm batteries on the first of every month. However, it is important to note that most current PDA models are rechargeable, eliminating the need to change batteries.
New Equipment

New equipment was purchased to replace the lost devices. This need for new equipment revealed that the Palm IIIxe model that was used in the project had become obsolete and was no longer sold in stores. This necessitated the purchase of a newer model (Palm m125) that would be compatible with the software being used. In addition, this change required the purchase of new Palm Modems because the ones being used previously were not compatible with the new devices. This is indicative of the rapid pace of handheld technology whereby the advent of newer and faster models with more memory capability and additional features often quickly usurp older models on the market. Compatibility of the server to work with new and old PDAs was also a problem initially, and several work sessions were required with all sites and the contractor to ensure successful syncing.

DISCUSSION

Using handheld devices to collect data for a study on elder neglect by caregivers has had both advantages and disadvantages. Aim 1 was to provide an easy to understand Palm-based data collection program in order to maximize efficiency in the ED. Although the program was easy for screeners to use, it was disappointing to find that, on the whole, screeners preferred to collect data using the traditional pen and paper method and later enter the data into the handheld devices for uploading instead of relying on purely “paperless” data collection. The reason for this preference is the difficulty in managing intensive patient interaction and technology at the same time. This could be countered by creating a program with more drop-down menus for variables, where value choices simply need to be tapped on as opposed to those that necessitate textual variables, which require Graffiti handwriting with the stylus. Moreover, there have been certain advantages to using both paper and handheld computer data entry, despite the concern of introduction of error. It affords the opportunity to have a hard copy backup of the patients’ screen data in the event of data loss, which would not be possible with data collection only using the handheld devices. Furthermore, paper-to-Palm transfer and uploading is more time efficient than paper data collection with data entry into a desktop computer. This is because the handheld devices are portable, allowing for assessment personnel to make this transfer during slow periods in their shifts in the ED instead of bringing all of the paper surveys back to the central office to be input at once. It should be noted, however, that screeners had to be even more careful with patient confidentiality using this method. Because data collection for this study has been conducted at multiple clinical sites, with the central offices at the academic and business institutions of the principal investigators, the portability of the devices has been a particularly useful advantage. In addition, it has been useful to have prompts in the software application that inform the assessment staff when a patient has not met the eligibility criteria of the study. Although, all of the screeners are well trained and know these criteria, this offers additional reassurance that the recruited patient is, in fact, eligible. Subjects have also responded well to the technology. Although many of the subjects involved in this study are older adults they have experienced no discomfort with the Palm in their presence, and, by contrast, the explanation of it as a data collection tool has served to build rapport with subjects.

Aim 2 of implementation, to minimize training needs, was met by the project. Six hours of training was adequate time to get the screeners comfortable with the instruments being used, the devices themselves, the data collection procedures, and for them to practice data entry and enter test cases for interrater reliability. Additional time practicing to write the stylus based character would have been helpful for screeners to overcome their reliance on paper data collection, particularly entering those variables that necessitated writing in Graffiti with the stylus. These variables include the patient name, address, and additional diagnostic comments.

Several problems existed in meeting aim 3 to insure secure data transfer to a central server using a common telephone hookup. Although data were secure during and after the transfer for the entirety of the project, connecting to a remote server through a modem and telephone was often frustrating because it often took several attempts to inevitably connect. Local “syncing” device (i.e., connecting and uploading the data to a desk top computer via a cable), or using newer technology such as transmitting data in a wireless fashion via infrared light waves (“beaming”) to a desktop could eliminate these problems. In fact, transfer-
ring data by beaming is increasingly common and modems rarely need be used anymore. Problems with using multiple Palm models on the same server have also been noted, but this can be avoided through the advance purchase of more PDAs than required.

RECOMMENDATIONS

Based on this ongoing experience with handheld technology for data collection, there are several recommendations for other researchers to keep in mind if they are considering using this technology in their research.

1. Have a backup plan for data collection on hand (e.g., paper surveys), in the event that problems are encountered and purely paperless data collection is not possible. Although PDA technology is increasingly more reliable, it is always useful to have such a plan in place.

2. Overbuy handheld devices by 25% to ensure sufficient replacement coverage for lost or broken devices to avoid compatibility issues.

3. Make sure the data is password protected to ensure security of files, especially in the event of loss.

4. Review data bimonthly to ensure data collected are complete and clean.

5. Where possible, use drop-down boxes as a coding mechanism to reduce errors and data entry time. This will also help build a rapport with subjects and decrease the propensity to use the standard pen and pencil instruments.

6. Use preprogrammed skip patterns. Screeners will have an advantage in data entry if irrelevant questions are automatically skipped.

7. Where large amounts of textual information are required, ensure screeners have portable handheld PDA keyboards.

8. Ensure that staff has a minimum of 10 hours of PDA training so that use in public is confident and efficient, especially in cases in which large amounts of textual data entry are required. This will increase the screeners’ ease of use, allow them to multitask more efficiently, and allow them to focus on their subjects more effectively during the screening process.

9. Use local syncing or infrared beaming to transfer data to a desktop computer as opposed to uploading by way of modem. These methods of transfer will be easier and more reliable.

10. In the case in which remote uploading through a modem is the only option, delete old data from handheld devices once they have been uploaded or synced to the mainframe to ensure future syncing success. Large files become difficult to send over the modem.

11. Sync recently acquired data in a file separate from data that has already been cleaned to maximize data efficiency.

CONCLUSION

The PDA is a relatively new technology that has enormous potential for clinical researchers. The project described in this article shows both the challenges and possibilities of incorporating handheld devices for data collection into a program of research. The lessons garnered from this experience can be used to improve the efficiency and effectiveness of the implementation and use of these devices. Furthermore, as handheld technology improves, it will become faster and easier to collect data electronically using PDAs. Although training and implementation of this technology does take time, in cases in which data collection covers multiple sites, large numbers of cases, or offers periods of decreased activity between field subjects, they offer a promising mechanism for data collection. The PDA is a relatively new technology that has enormous potential for clinical researchers.

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REFERENCES


