Journal of Medical Systems, Vol. 29, No. 4, August 2005 (© 2005)
DOI: 10.1007/s10916-005-5893-y

A Review on Diffusion of Personal Digital Assistants in Healthcare

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This review draws from a comprehensive literature search and reviews the adoption, usage and impact of personal digital assistants (PDAs) in healthcare. Adoption relates to the rationale for, barriers to and scope of adopting PDAs. Usage relates to the types of health professionals using PDAs, and their functionalities and features. Impact relates to perceived outcomes, actual outcomes and improved productivity from PDA use. The review shows that although PDA adoption and usage in healthcare are growing, there are very few studies that provide evidence-based results about impacts of such adoption and use. However, the preliminary impact studies that have been done have shown promise with regards to PDA use improving patient outcomes. We feel this review will increase awareness and encourage research about PDAs and their use in healthcare.

KEY WORDS: personal digital assistant; diffusion; healthcare; review.

INTRODUCTION

Personal digital assistants (PDAs) have been adopted and used within many disciplines for a number of different functionalities and healthcare is no exception. Healthcare professionals from physicians to pharmacists have adopted PDAs. That adoption has led to a number of different uses including decision support, education, and accessing or collecting data.

The adoption, usage, and impact framework was based on Cooper and Zmud's model of IT implementation. The new IT implementation moves through six stages: initiation, adoption, adaptation, acceptance, routinization, and infusion.(1) This article presents literature-based papers in relation to PDA implementation in health, examining issues surrounding adoption, usage, and impact, so as to illuminate the popularity and impact of PDAs within the healthcare environment. The databases searched were Medline, Embase, Cinahl, HealthStar, Best Evidence AMED, and

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Table I. Articles Cited in Adoption Section Listed by the Subsections

Section title	Authors (see reference for details)
Adoption	
Rational	Yamamoto 2000
Barriers	Duncan 2000; Fowler 2002; Hunt 2002; Lapinsky 2001; Luo 2001; Marks 1999; Yamamoto 2000
Scope	Criswell 2002; Martin 2002; Taylor 2001

MD Consult. The literature for this review was obtained from a literature search for the year 1990 through 2001 for all of the databases, and 1990–2003 for Medline and Cinahl. The search criteria included general terms such as PDA, handheld, and palm top, as well as more specific terms such as Palm OS, Windows CE, and Newton OS. The articles are presented in three sections: adoption, usage, and impact. Each of these three sections is further divided into subsections. A table is created for each section that summarizes the articles by subsection.

ADOPTION

Rationale

The reasons cited in the articles for adoption of PDAs (See Table I for a listing of articles cited in the adoption section) within healthcare include improving clinical decision making, medical education, capture of clinical information, and surveillance of patient care. Although PDAs have been around since the early 1990s, it has only been over the last few years that they have become widely adopted. Early versions of PDAs, such as the Newton Message pad by Apple were largely rejected because of their large size, high cost, and low processing power. The introduction of the first Palm Pilot in 1996 effectively started the PDA revolution. For general PDA use in society, Palm is the most popular PDA system with an estimated 70% of the PDA market. Healthcare shows a similar trend towards Palm. Of the search articles retrieved where the PDA systems were identified, 15 were Palm, 9 were Newton, 3 were Windows CE, and 5 were Psion. The general trend seen was that Newton systems were more popular in the mid 1990s (seven of the nine Newton articles were before 1998) whereas Palm and Windows gained popularity in the late 1990s and into the 21st century. A number of reasons cited for adoption of PDAs include convenience such as weight, portability, and connectivity,[2] inexpensive cost, and ease of accessibility to software. Software for PDAs can be locally developed or downloaded from freeware or subscription sites. A number of software are available for local PDA application development including Pendragon Forms, Satellite Forms, Metrowerks CodeWarrior, and diaSYNC.

Barriers

Barriers to PDA adoption included slow speed of images being obtained, as in radiology images,[2] or other connectivity problems, small screen size,[3] lack

of available software or programs for specific areas of healthcare, such as critical care,[4] and patient data security concerns.[5–7] Barriers not related to technical design can also cause problems for full adoption of a PDA project. One study on PDA use for wireless entry of healthcare data described how it took 6 months to design the database and other such design details for data entry, but compliance with HIPPA and institutional information service confidentiality requirements added an additional 8 months before implementation.[8]

Scope

Healthcare has seen adoption of PDAs grow in recent years. PDA adoption as part of everyday practice by physicians grew from 10% in 1999 to 18% in 2001.[9] Looking at Canada, the 2002 Physician Resource Questionnaire reported that 28% of Canadian Physicians use a PDA in clinical practice, a 47% increase over 2001.[10] A 2002 study on the use of handheld computers in family residency programs showed that two-thirds of 306 surveyed family residency programs had already adopted handheld computers for use within the residencies, and an additional 14% of residency programs indicated plans for adoption in the next 24 months.[11] The same study also reported that of the programs that adopted handheld computers, 45% had mandatory handheld applications (i.e. software programs) that are used routinely by all users. Of residency programs that adopted handheld computers, funding for the handheld computers and related applications was non-budgeted in 76% of the programs, and programs with handheld computer budgets averaged $461.58 (US) per user.[11] One of the most popular adoptions of PDAs was during the formal education or training of medical residents and other health professionals. A number of papers involved PDA use at the resident training level. The medical specialties adopting PDAs for resident training included family practice, internal medicine, surgery, emergency medicine, pediatrics, and obstetrics. PDAs were also used in the training of pharmacy residents and nurses.

The literature shows that adoption of PDAs is growing and it appears that it will continue to grow. Under the subsection “Scope” it was described how a growing percentage of medical residency programs are adopting PDAs and some programs are using mandatory PDA applications. That implies a shift of adoption rational from strictly using PDAs as an information source or data collection tool to using PDAs as an iatrical part of medical practice. The emergence of more advanced PDAs and continually evolving PDA software are starting to remove some of the technology barriers that plagued the early years of PDA use. Security and privacy barriers, as illustrated in the HIPPA example above, may prove to be the biggest barrier to PDA use in the years to come.

USAGE

Types of Users

There are a variety of health professionals who use PDAs (See Table II for a listing of articles cited in the usage section) including physicians, nurses, emergency

Table II. Articles Cited in Usage Section Listed by Functionality of Use

Functionality of use	Authors (see reference for details)
Clinical decision support	Andrade 2001; Davidson 2002; Holman 1996; Schrezenmeir 2002; Shiffman 2000
Patient surveyor tools	Anonymous 2002; McBride 1999; Morlock 2001; Saleh 2002; Stubbs 2000; Stubbs 2001; Taylor 1990
Computerized patient record	Bologna 2002; Luo 2001; Reilly 2001; Rothschild 2002
Clinical data repository	Duncan 2000; Wang 1999; Yamamoto 2000

medical technicians, and pharmacists. Likewise, a number of different domains (e.g. fields of medicine such as internal medicine, pediatrics or orthopedics) were found with regard to PDA use in healthcare.

Functionalities

Key functionalities of healthcare being studied included clinical decision support systems, clinical data repository, patient surveyor tools, and computerized patient records. Each functionality of use described above is briefly summarized below and provided with examples

(a) PDAs as a clinical decision support system includes uses by both physicians and patients. Specific physician decision support uses included guideline adherence for monitoring conditions such as asthma,[12] and blood cholesterol monitoring and management.[13] Patient decision-support use included self-monitoring of diseases such as diabetes and HIV. Two studies involved monitoring of diabetes by providing optimal insulin dose based on diet.[14,15] HIV monitoring is designed to keep the patients on track with their antiretroviral therapy more effectively using a pocket sized computer application called the 'Disease Management Assistance System', which electronically tells patients when to take their medications and what side effects to monitor.[16]

(b) Patient surveyor tools have mainly been used for real-time tracking of data related to diseases or conditions. Diseases or conditions tracked included appetites and eating disorders,[17,18] behavioral and psychological disorders,[19,20] and orthopedic surgery or procedure outcome measures.[21–23]

(c) PDA use as a computerized patient record has been cited as facilitating more efficient and organized collection of medical data.[24] Another documented usage of computerized records is to reduce medical errors in different areas of healthcare. Patient and specimen identification during blood collection[25] and tracking of pharmacist interventions[26,27] are the two areas using handheld computers to try and reduce errors.

(d) Clinical data repository use includes physicians accessing data, reports, or images through the PDA. The range of users included physicians accessing general patient data or records [3] to specialists such as cardiologists accessing electrocardiograms[28] and neurologists viewing CT scans for neurological assessments.[2]

Table III. Articles Cited in Impact Section Listed by Impact Type

Section title	Authors (see reference for details)
Impact	
Perceived outcomes	Andrade 2001; Davidson 2002; Holman 1996; Rothschild 2002
Actual outcomes	Schrezenmeir 2002; Shiffman 2000
Improved productivity	Bird 2001; Nicolaou 2001

As with adoption, of PDAs literature has shown the usage of PDAs to be growing. The number of users, both health professionals and patients, have grown and so has the number of domains where PDAs are being used. The biggest usage growth was as a clinical decision support tool, and patient surveyor tool, and the literature illustrates real potential for using PDAs for real-time tracking of patient diseases or conditions.

IMPACT

The first two types of impacts of PDA use in healthcare that will be discussed are actual and perceived outcomes (See Table III for a listing of articles cited in the impact section). We are defining outcomes as patient health outcomes. The third type of impact is improved productivity, which implies improved productivity in work processes.

Perceived Outcomes

Because of the recent emergence of PDAs, there are not many studies that illustrate defined outcomes or other results of use. Many of the studies to date have expressed perceived opinions about PDA software, ease of adoption, or improved outcomes from use but few studies have presented real evidence about patient outcomes or delivery of care. For example, one study on using ePocrates Rx for drug information reported physicians as saying they felt it improved decision-making and reduced the rate of adverse drug events, however the study offered no formally obtained results to collaborate the claim.[27] The cholesterol guideline study by Davidson[13] reported that although Palm Pilot cholesterol risk calculators appear to increase usage and compliance of cholesterol guidelines and screening aids, it would be sometime before clinical impacts such as reduced heart disease or reduced use of cholesterol medications are seen. Likewise, the HIV monitoring system appears to improve compliance with antiviral therapy but again it will be sometime before clinical implications are realized.[16] The diabetes study by Holman [14] *et al.* reported encouraging outcomes with PDA usage for regulating insulin, but the study had a small number of subjects[6] and did not provide any formal clinical outcomes.

Actual Outcomes

For the 5 studies described in the clinical decision support subsection of the usage section above, 2 studies report actual outcomes and the results to be varied.

The diabetes study by Schrezenmeir *et al.*[15] provided clinical data values and positive outcomes showing significant decreases in mean blood glucose, hypoglycemic episodes, and hemoglobin A1C in the group using pocket computer assisted insulin regulation. The Shiffman[12] study on asthma guidelines reported PDA use increased the length of both patient visits and fees for service, but no short-term clinical improvements in asthma management were seen for the patient cases within the study.

Improved Productivity

Some impact results have come from the many studies on using PDAs as a medical education tool (described in the adoption section above), and some of the results have shown positive utility in the form of improved productivity. One study reported that a group of emergency medicine residents using PDAs to document patient procedures, encounters, and follow-ups had significantly increased mean documentations of certain procedures than a control group using traditional index cards.[29] Likewise, it was reported that a handheld procedural log for medical residents featured high data integrity and reliability, low data entry workload, and rapid feedback for residents and program directors about resident's procedural experience.[30]

Impact, arguably the most important aspect of PDA diffusion is also the most difficult aspect to assess. The studies with perceived outcomes show promise, yet as mentioned above it may be some time before actual patient outcomes are realized from PDA use. And, it is possible that the promise of improved patient outcomes from PDA use may not be realized. Out of the 2 studies with actual outcomes, only 1 showed clinical improvement for patients.

DISCUSSION

This review has provided an illustration of the diffusion of PDA in healthcare. We began with adoption; followed by how adoption leads to actual usage. We concluded by providing some insight to the impact of PDA in healthcare. Although literature has shown that PDA adoption has increased over the last few years, and the trend appears to be that adoption will continue to increase, there are few articles that show how PDA adoption impacts healthcare work routines and work processes. Evaluation studies must be done to show that the implementation of technology such as PDA does not take precedent over patient care but actually helps to improve patient care. Simply using PDAs will not necessarily improve patient care, as illustrated in the asthma paper.[12] Further research which shows that PDA implementation can improve both work processes and patient care would help make a strong case for why healthcare institutions should adopt and use PDAs. Impacts of PDAs are certainly an area that requires more rigorous studies to provide the evidence needed to demonstrate further outcomes and productivity of PDA diffusion. As discussed earlier, much of the current outcome data are opinions and descriptive information about perceived outcomes. Formal evaluation methods such

as randomized control trials are one way to provide more definitive evidence about the impact PDAs have on both patient outcomes and caregiver satisfaction. We feel the information presented in this review will increase awareness about the current state of adoption, usage, and impact of PDAs in healthcare and also encourage research to further enhance the use of PDAs in healthcare.

REFERENCES

1. Cooper, R. B., and Zmud, R. W., Information technology implementation research: A technological diffusion approach. *Manag. Sci.* 36(2):123–139, 1990.
2. Yamamoto, L. G., and Williams, D. R., A demonstration of instant pocket wireless CT teleradiology to facilitate stat neurological consultation and future telemedicine implications. *Am. J. Emerg. Med.* 18(4):423–426, July 2000.
3. Duncan, R., and Shabot, M. M., Secure remote access to a clinical data repository using a wireless personal digital assistant. *In Proceedings of AMIA Symposium.* 210–214, 2000.
4. Lapinsky, S. E., Weshler, J., Mehta, S., *et al.*, Handheld computers in critical care. *Criti. Care.* 5(4):227–231, 2001.
5. Luo, J., Hales, R., Hilty, D., *et al.*, Clinical computing: Electronic sign out using a personal digital assistant. *Psychiatr. Serv.* 52(2):173–174, February 2001.
6. Marks, I., Computer aids to mental health care (Review 75 Refs). *Can. J. Psychiatr.* 44(6):548–555, August 1999.
7. Hunt, E. C., The value of a PDA to a nurse. *Tar-Heel-Nurse.* 64(3):18–19 (3 ref), May-June 2002.
8. Fowler, D. L., Hogle, N. J., Martini, F., and Roh, M. S., The use of a personal digital assistant for wireless entry of data into a database via the Internet. Surg. Endosc. 16(1):221–223, January 2002.
9. Taylor, H., and Leitman, R., Physicians' use of handheld personal computing devices increases from 15% in 1999 to 26% in 2001. *HarrisInteractive.* 1(25), August 2001.
10. Martin, S., More hours, more tired, more to do: Results from the CMA's 2002 Physician Resource Questionnaire. *Can. Med. Assoc. J.* 167(5), September 2002.
11. Criswell, D. F., and Parchman, M. L., Handheld computer use in U.S. family practice residency programs. *J. Am. Med. Inform. Assoc.* 9(1):80–86, January–February 2002.
12. Shiffman, R. N., Freudigman, K. A., Brandt, C. A., *et al.*, A guideline implementation system using handheld computers for office management of asthma: Effects on adherence and patient outcomes. *Pediatrics.* 105(4):767–773, 2000.
13. Davidson, M. H., Strategies to improve adult treatment panel III guideline adherence and patient compliance. *Am. J. Cardiol.* 89(5A):8C–20C; discussion 20C–22C, March 2002.
14. Holman, R. R., Smale, A. D., Pemberton, E., Riefflin, A., *et al.*, Randomized controlled pilot trial of a hand-held patient-oriented, insulin regiment optimizer. *Med. Inform.* 21(4):317–326, 1996.
15. Schrezenmeir, J., Dirting, K., and Papazov, P., Controlled multicenter study on the effect of computer assistance in intensive insulin therapy of type 1 diabetics. *Comput. Methods Programs Biomed.* 69(2):97–114, August 2002.
16. Andrade, A., HIV adherence strategies take a high-tech route. *Aids-Alert.* 16(8):97–98, August 2001.
17. Stubbs, R. J., Hughes, D. A., Johnstone, A. M., *et al.*, The use of visual analogue scales to assess motivation to eat in human subjects: A review of their reliability and validity with an evaluation of new hand-held computerized systems for temporal tracking of appetite ratings. *Br. J. Nutr.* 84(4):405–415, 2000.
18. Stubbs, R. J., Hughes, D. A., Johnstone, A. M., *et al.*, Description and evaluation of a Newton-based electronic appetite rating system for temporal tracking of appetite in human subjects. *Physiol. Behav.* 72(4):615–619, 2001.
19. Taylor, C. B., Fried, L., and Kenardy, J., The use of a real-time computer diary for data acquisition and processing. *Behav. Res. Ther.* 28(1):93–97, 1990.
20. Anonymous, Hand-held devices ease burden of behavioral health assessment. *Dis. Manag. Advis.* 8(10):152–156, 145, October 2002.
21. McBride, J. S., Anderson, R. T., and Bahnson, J. L., Using a hand-held computer to collect data in an orthopedic outpatient clinic: A randomized trial of two survey methods. *Med. Care.* 37(7):647–651, July 1999.
22. Morlock, M., Schneider, E., Bluhm, A., *et al.*, Duration and frequency of every day activities in total hip patients. *J. Biomech.* 34(7):873–881, July 2001.

23. Saleh, K. J., Radosevich, D. M., Kassim, R. A., *et al*., Comparison of commonly used orthopaedic outcome measures using palm-top computers and paper surveys. *J. Orthop. Res.* 20(6):1146–1151, November 2002.
24. Luo, J., Hales, R., Hilty, D., *et al*., Clinical computing: Electronic sign-out using a personal digital assistant. *Psychiatr. Serv.* 52(2):173–174, February 2001.
25. Bologna, L. J., Lind, C., and Riggs, R. C., Reducing major identification errors within a deployed phlebotomy process. *Clin. Leadersh. Manag. Rev.* 16(1):22–26, January–February 2002.
26. Reilly, J. C., Wallace, M., and Campbell, M. M., Tracking pharmacist interventions with a hand-held computer. *Am. J. Health Syst. Pharm.* 58(2):158–161, January 2001.
27. Rothschild, J. M., Lee, T. H., Bae, T. *et al*., Clinician use of a palmtop drug reference guide. *J. Am. Med. Inform. Assoc.* 9(3):223–229, May–June 2002.
28. Wang, J. K., and Duncan, R., Handheld computers in residency training: Development of a mobile medical records system. *Pediatrics.* 104(3):672, 1999.
29. Bird, S. B., Zarum, R. S., and Renzi, F. P., Emergency medicine resident patient care documentation using a hand-held computerized device. *Acad. Emerg. Med.* 8(12):1200–1203, December 2001.
30. Nicolaou, D. D., and Davis, G. L., A distributed asynchronous resident procedure log for hand held devices. *Acad. Emer. Med.* 8(8):583, 2001.