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Using Handheld Technology to Monitor Diabetes in Remote Communities*

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ABSTRACT

Handheld technology in a telemedical environment offers an unprecedented opportunity to bring healthcare to remote regions of the U.S. It provides a portable and low cost means of proactively monitoring health in order to promote quality and longevity of life. Handheld technology, in the form of a PocketPC, is proposed in this study to be used during home visits by healthcare providers and by patients for the daily monitoring of diabetes. It is proposed that PocketPC technology be integrated into an information communication technology (ICT) accessibility framework in order to minimize the risk of failure due to social and human factors. The PocketPC technology, within the context of this framework, is discussed along with future research opportunities.

INTRODUCTION

There is a healthcare crisis in many remote communities in the U.S. due to a lack of facilities, clinicians, support staff, and other medical resources. Health statistics in remote tribal communities in the U.S. reflect this critical situation in managed healthcare. Diabetes is epidemic in most tribal communities with approximately 15 percent of those receiving healthcare from Indian Health Services diagnosed with type 2 diabetes (National Diabetes Clearinghouse Center, 2002). The American Cancer Society identified fewer than 90 doctors per 100,000 Native American compared to 229 per 100,000 in the U.S. general population (American Cancer Society, 1997). Often times, patients wait for months to get an appointment or resort to emergency room visits to obtain critical healthcare. The number of patient visits to the Phoenix Indian Medical Center illustrates the strain on existing healthcare resources, as it has a capacity for 40,000 annual outpatient visits but handled 250,000 during a one year span (Nichols, 2002).

Geographic isolation, income levels, normal aging, and chronic illness compound the problem. For many in remote areas, the nearest health facility may be over a hundred miles from the patient's home. Employment opportunities in these areas are sparse with traditional means of income generation producing low per capita income. Healthcare options are limited because income levels below the poverty line preclude adults from affording private health insurance. For older adults sixty years and older, vision, cognition, and physical disabilities due to normal aging or chronic illness impede mobility. As a result, older adults in remote areas become even more isolated and homebound than their urban counterparts.

Adult literacy also plays a role in receiving proper healthcare in many communities. The inability to understand health material is a life-threatening barrier especially when it goes undetected. Health knowledge enables individuals to manage diseases and make treatment decisions; and without this knowledge, an individual may find it difficult to manage illnesses resulting in complications and health deterioration (Morrell, et al., 2002). Healthcare organizations report that adult reading levels vary between fifth and eighth grade.[1] Yet, comprehending medical instructions on pamphlets, prescription drug labels, and other written materials often requires at least a high school education.

Age may also have an impact on literacy such that comprehension of written material progressively declines. Researchers have found that literacy declines dramatically with age, even after making adjustments for level of education and cognitive impairment (Gazmararian, et al., 1999). As one ages, it becomes more difficult to simultaneously remember and process new information and to comprehend text (Craik and Salthouse, 2000).

What is needed is a technological means of bringing managed healthcare to remote patients while taking into account the social and human aspects of these communities. Limited medical staff and resources require innovative ways of proactively managing personal healthcare with sensitivity to the demographic profile of these patients.

TELEMEDICINE

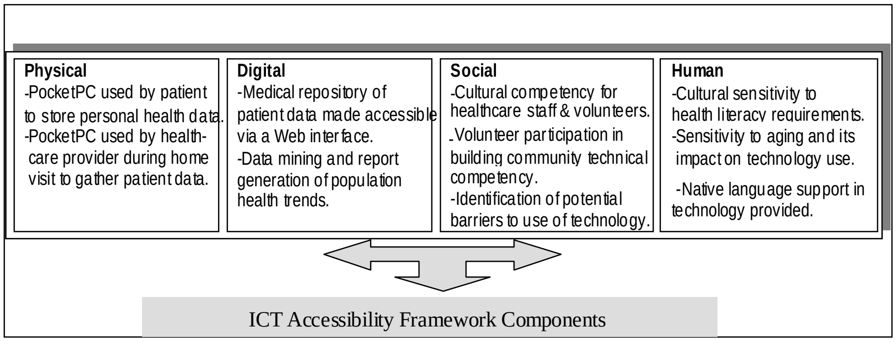
The challenge of providing universal healthcare is particularly pressing for remotes areas when income, mobility, literacy, and healthcare resources are taken into account. Research is needed to develop new technologies for improving quality and longevity of life regardless of geographic remoteness. Telemedicine is growing in popularity as a means of providing health services to remote areas. It is broadly defined as the use of information and communication technology (ICT) to provide medical information and services (Perednia and Allen, 1995).

Telemedicine has been pursued for over three decades as researchers, healthcare providers, and clinicians search for ways of reaching patients in remote and isolated areas (Norris, 2001). Early implementation of telemedicine focused on the use of the telephone and fax machines for interaction between healthcare providers and patients. Though many of these early projects did not survive, telemedicine has been resurrected during the last decade. The Internet in particular has changed the way in which medical consultations can be provided. Personal computers and supporting peripherals, acting as clients, can be linked to medical databases residing virtually in any geographic space. Multimedia data types, video, audio, text, imaging, and graphics, promote the rapid diagnosis and treatment of diseases.

Mobile devices using wireless connectivity are also growing in popularity as thin clients that can be linked to medical data sources. These devices provide for local data storage, from which data can be wirelessly transmitted to and from a centralized source. Personal digital assistants (PDAs)2 are mobile devices that are typically considered more usable for multimedia data than smaller wireless devices (e.g., cell phones). They offer a larger screen size, fully functional keyboards, and operating systems supporting many desktop features. They are portable and lightweight, and they offer similar functionality as personal computers scaled back to accommodate the differences in user interface designs, data transmission speed, memory, processing power, data storage capacity, and battery life.

Our research efforts have initiated the study of the PocketPC with the Microsoft Windows CE operating system as a means of monitoring diabetes for patients living in remote areas. The PocketPC was selected because of its feature set including cellular capabilities, built-in digital camera, and support of multimedia data formats. In addition, it is

Figure 1. ICT Accessibility Framework for Promoting Healthcare in Remote Communities



significantly lower in cost than other computing technologies including a laptop or personal computer. Data entered into the PocketPC is stored in a local, relational database that later can be transmitted to a centralized data source.

The introduction of telemedicine in remote areas is doomed to fail when social and human aspects are not taken into account. As such, we propose the use of an information and communication technology (ICT) accessibility framework to promote the effective use of our PocketPC telemedical system in these communities.

ICT ACCESSIBILITY FRAMEWORK

Past administrations in the federal government promoted technology initiatives by providing resources to introduce ICT into underprivileged communities. The objective was to "bridge the digital divide" in order to improve quality and longevity of life, address social problems, and promote educational advancement in these communities. However, many have given up on the concept of using ICT in innovative ways to reach underprivileged communities. Numerous dead Web sites, unused equipment, and outdated software are testimonials to failed attempts at bridging the divide. Though ICT is often blamed for the failure of community technology projects, in many cases it was the human and social systems that caused the failures (Jarboe, 2001; Patterson and Wilson, 2000; Warschauer, 2002).

It is proposed in this work that ICT, in the form of a PocketPC wirelessly linked to a central data source, is a viable solution for monitoring diabetes in remote areas of the U.S. Unlike other failed ICT community projects, the proposed technology would not be used in isolation of the social and human aspects of its use. It would be used within the context of an ICT accessibility framework, as outlined by Warschauer (2002). Physical, digital, human, and social resources, as shown in Figure 1, would play an equal role in ensuring the successful application of the PocketPC in a telemedical environment.

The physical resources are information and communication components used to provide healthcare services. The digital resources are the online materials that support personal health maintenance and assist in the analysis of health trends. Social resources focus on identifying and eliminating cultural and social barriers in the use of technology and developing cultural competency for each researcher, healthcare partner, and volunteer; as well as, promoting collaboration with community members in developing technical expertise at a local level. Human resources focus on literacy requirements given the demographic profile of the region taking into account English as a first language. It also accounts for aging factors that may pose as barriers to the use of technology if not addressed early in the design of telemedical systems.

- **Physical Resources** – PocketPC technology is the basis for managing diabetes and promoting health literacy. This technology offers unprecedented portability in gathering personal information about health, diet, exercise, and medication use. In addition, it provides compact data storage, wired and wireless connectivity to a central data source, and immediate access to personalized information about diseases, treatments, medications, diet, foot wear, and medical devices. It is relatively inexpensive when compared to other personal computing environments.
- **Digital Resources** - Patient and community report capabilities are made possible through the use of a PocketPC during home visits and by daily monitoring of diabetes by patients. The data entered into the PocketPC by a healthcare provider or patient is gathered in a centralized data source, which can be used to monitor individual and community health trends. Data mining techniques can be applied during the analysis of large data sets resulting in both analytical and predictive reporting capabilities.
- **Social Resources** - Social, cultural, and technological barriers are studied in order to gain community acceptance and support in the use of the proposed technology. From a patient perspective, technology skills, comprehension of personal health, English proficiency, health literacy, and past experiences, may all impact whether the patient uses the PocketPC home monitoring system effectively. Any of these factors may result in a patient being resistant, anxious, or fearful of the use of technology to monitor diabetes. A patient, and the community as a whole, may be skeptical of this technology because of previous exploitation or a perception of little or no benefit from its use. It is important to address potential barriers early in the introduction of technology in order to obtain widespread acceptance.
- **Human Resources** – The effective use of PocketPC technology in this environment requires sensitivity to health literacy issues that might impact it. Reading complex medical terminology associated with pharmaceuticals, medical devices, diseases and treatments can be overwhelming to a person reading at a lower grade level or for whom English proficiency is low. There may be severe consequences when a person does not comprehend medical instructions related to monitoring her or his health (Hilts, and Krylik, 1991). Patients may be confused by the complexity of the instructions thus ignoring or misinterpreting them (Smith and Smith, 1994). To address these potential barriers, user interface designs and information content must take into account the health literacy needs of the targeted user. In most cases, this requires supplementing text with pictures and writing content no higher than a sixth grade level.

The design of the home monitoring system must take into account other user characteristics in developing the PocketPC interface. User characteristics include: past use of technology, education, age, vision, and physical impairments. Because of the high number of older adults with diabetes, normal aging factors must also be taken into account in the design of the user interface. As such, a usable design focuses on the good use of color and images to effectively relay information while accounting for vision degradation due to aging. Many older adults, in particular, experience a loss in hand and finger dexterity thus making typing, scrolling (Hawthorne, 2000), and mouse clicking (Ellis and Kurniawan, 2000) difficult. Simple interface designs are needed in order to gain widespread acceptance of the proposed technology.

THE POCKETPC AND TELEMEDICAL SUPPORT

Though PDA's are typically used to store schedules, phone numbers and addresses, send and receive email, and play games; they have the technological capability to do much more. Recent technological advances allow for relational data storage on local devices. This data can be moved to a central source using: wireless transmission, synchronization with a PC, or a secondary storage device.

The Viewsonic® (V36) PocketPC is used in this study to store personal health data in its local database, which mirrors parts of a centralized database. The PocketPC is being used because it is inexpensive at a few hundred dollars per unit. Peripheral devices are also low in cost offering a means of storing data and printing documents. The PocketPC may be supplemented with cellular capability in order to send and receive data from the centralized source. The PocketPC uses rechargeable batteries thus eliminating the sole reliance on home electricity for data gathering and dissemination. It also has digital camera capabilities, which is extremely important for the daily monitoring of foot sores associated with diabetes.

PocketPC technology is being developed to support both healthcare providers conducting home visits and patients using it daily to monitor their diabetes. The focus is on foot health given the high amputation rate in many remote communities. Each of these proposed uses of PocketPC technology is briefly described.

Healthcare Provider Support

The healthcare provider uses the PocketPC in order to gather information about a patient's diabetes while conducting a home visit. The PocketPC device is very useful in this environment because of its portability and support of multimedia data including digital images, audio recordings, and text-based content. Information gathered by the healthcare provider includes a thorough analysis of the patient's foot in order to uncover potential foot wounds. This information, along with other healthcare data, is entered into the local database residing on the device. Once the visit is completed, the healthcare provider is able to enter notes (handwritten using the stylus pen or typed using the built-in or peripheral keyboard), schedule appointments, make referrals all of which are stored as part of the patient visit record.

The user interface of the device is modeled after the comprehensive diabetes foot form that is currently used by health clinics across the U.S. It is a standard mechanism for assessing foot health data during a patient visit. The screen size of the PocketPC is prohibitive in showing the foot form as a whole. As shown in Figure 2, the form has been decomposed into a set of screens into which the healthcare provider enters data.

Home Monitoring

The PocketPC enables a diabetic patient to enter data on a regular basis to promote healthy feet. This information would relate to personal health, persistent foot wounds, and medication use. The PocketPC can be programmed to generate reminders (e.g., "Did you wash your feet today?), and provide supplemental information about diet and exercise. Figure 3 shows several screen designs from the home monitoring system. The user enters information about the condition of his or her right foot. There is native language and visual support of the question being asked. The video capability would allow the user to take a picture of a wound that is stored as part of patient data. The information gathered is used by a healthcare provider for ongoing assessment of the patient's health.

The home monitoring system has usability issues that need to be addressed during the design of its user interface inclusive of health literacy, vision, and unsteady hands. This is particularly important for older adults due to normal aging and its impact on the use of technology. Information must be provided at an appropriate reading grade level in alignment with the user's reading comprehension skills. In our work, a fifth grade reading level is targeted for all information content provided to the patient. To account for unsteady hands, data entry must be kept simple with no typing required. The user interface of the home monitoring system can only use buttons or pull-down lists to illicit patient responses. Information content must be visible in terms of font size, type, and color in order to accommodate users with degrading vision. For users with low English proficiency, it is important to have audio support such that information content is read aloud in a native language. In our design, each screen would be supplemented with an audio version in the user's native language. To keep information content simple, pictures provide supplemental information (shown in Figure 3).

Figure 2. Screen Snapshots of Foot Form Used to Monitor Diabetes

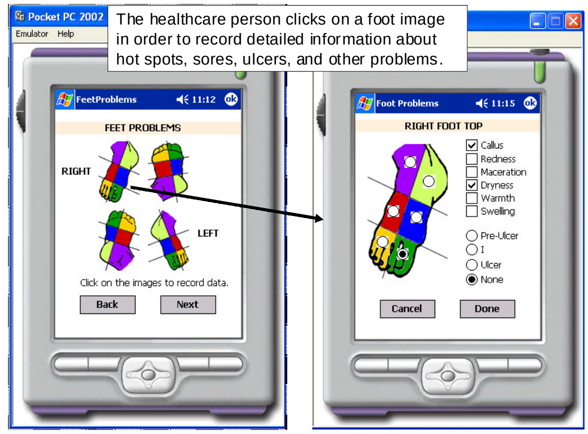
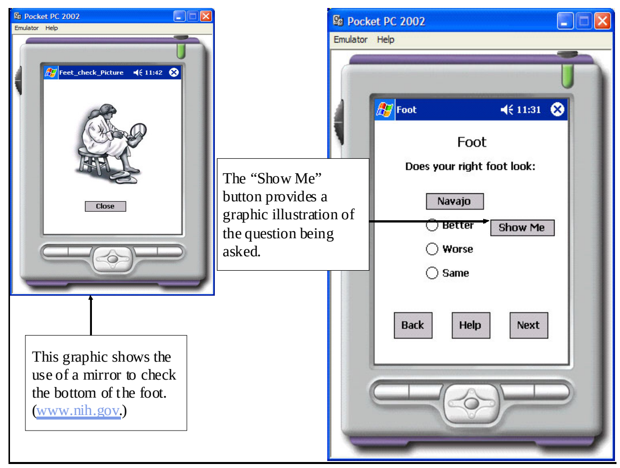


Figure 3. Screen Snapshots of the Patient's Home Monitoring System



FUTURE RESEARCH

There are environmental issues that have yet to be addressed in order to make this technology viable in remote areas where electricity and wireless communication are not available. This requires further study in the viability of PocketPCs when other energy sources are made available. The battery life of a PocketPC remains a potential barrier in terms of backup and recovery support of the device. Technological constraints associated with the Windows CE operating system do not allow for easy database recovery when the battery loses its charge. XML and other technologies are being explored as potential alternatives to storing local data until this problem can be resolved.

In terms of the human factors component of the ICT accessibility framework, usability studies are needed to determine whether the PocketPC is a viable means of remotely monitoring diabetes. A potential barrier to its use is the number of screens that a patient would traverse in answering questions about foot care and personal health. Usability studies are also needed to identify the impact of navigational complexity on the use of this technology by targeted users. From a healthcare perspective, patient data would include foot health, glucose level, blood pressure, diet, exercise, footwear, alcohol consumption, smoking, and more. However, a patient may have a threshold in terms of the amount and type of information entered especially if used on a daily basis.

The home visit component has undergone initial usability testing by a healthcare provider specializing in diabetes and foot care. For this particular use of PocketPC technology, there is little deviation from the standardized foot form that is currently being used. A significant difference, however, is that these foot forms are currently stored as paper copies in patient files. With the automated environment that would be provided by this research, significant data mining opportunities exist to assess community health trends.

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ENDNOTES

1 The American Academy of Family Physician's Health Education Program (American Academy of Family Physicians Health Education Program**;** 2002) recommends 7th grade or lower reading grade level. The National Work Group on Literacy and Health (National Work Group on Literacy and Health; 1998) recommends a fifth reading grade level. The University of Utah's Health Sciences Center (University of Utah Health Sciences Center; 1997) recommends a sixth-grade reading level.

2 PocketPCs, Palm Pilots, and other handheld devices are referred to as PDAs in this paper.

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