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Evaluation of an application for making palmtop computers accessible to individuals with intellectual disabilities

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Abstract

Background Palmtop computers provide a promising mobile platform to address barriers to computer-based supports for people with intellectual disabilities. This study evaluated a specially designed interface to make navigation and features of palmtop computers more accessible to users with intellectual disabilities.

Method The specialised cognitively accessible interface was compared with a standard Windows CE interface. Participants completed a structured set of navigation/computer use tasks using both the experimental and control conditions. Measurements included the amount of assistance needed and errors made in completing the navigation/computer use tasks.

Results Participants ($N=32$) made significantly fewer errors ($p<.001$) and required significantly fewer prompts ($p<.001$) while using the specialised software interface compared to the mainstream Windows interface.

Conclusions The research demonstrates the feasibility of using special software design methods, such as linear program flows, error minimisation and the incorporation of repetition and consistency, to improve access to palmtop computers for individuals with intellectual disabilities. Issues related to designing cognitively accessible interfaces are discussed.

Keywords: *Intellectual disability, palmtop, computer, accessibility, interface*

Introduction

People with intellectual disabilities typically have difficulty understanding abstract concepts (Hayes & Conway, 2000; Schalock et al., 2002), generalising learned information from one situation to another, and with reading and writing skills. More and more, however, developers of assistive and other technologies are recognising the potential for computer technology to help these individuals complete various tasks without the assistance of others. Computer-based technologies have been effective as a means of increasing capacity for adolescents and adults with intellectual disabilities across multiple domains, including vocational and employment skills (Davies, Stock, & Wehmeyer, 2001; Lancioni, Dijkstra, O'Reilly, Groeneweg, & Van den Hof, 2000; Stock, Davies, Secor, & Wehmeyer, 2003), augmentative communication (Hetzroni, Rubin, & Konkol, 2002; Romski & Sevcik, 1996), orientation and mobility (Lancioni, Oliva, Formica, & Rossetti, 1988; Lancioni, Oliva, Raimondi, & Ciattaglia, 1989), and independent living skills (Davies, Stock, & Wehmeyer, 2003a, 2003b; Holzberg, 1994, 1995).

There are, however, a number of issues that limit the utility of computer-based supports for people with intellectual disabilities. Desktop computers are not portable and notebook or tablet PCs, which are more portable, remain more expensive. Desktop, notebook, or tablet PCs all require people to type or write for input of data and information, and desktop and notebook PCs often require the use of a mouse or touch-pad, all of which can provide barriers to people with cognitive disabilities. Operating systems and most mainstream software programs remain too complex for people with intellectual disabilities to use. Typical computer programs offer a myriad of interface choices at any given time, many of them providing multiple input options for the same output (e.g., text menu, key-board shortcuts, button toolbars). It is often the case that people with intellectual disabilities have some level of difficulty understanding the abstract concepts and metaphors used in technology devices, not only at the language ability level, but in areas more closely related to reasoning. For example, beyond the need to understand that the words "file" or "folder" refer to something different when in the context of a

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computer system, computer users must also conceptualise the virtual location of these files within a computer directory. Indeed, many mainstream novice computer users have difficulty retrieving computer files due to their lack of understanding of the concepts of ''locations'' and of ''electronic'' data storage (Wehmeyer, Smith, Palmer, Davies, & Stock, 2004).

Palmtop computers provide a particularly promising platform to address some of these barriers to computer-based supports for people with cognitive impairments. These devices are portable, relatively affordable, customisable, capable of handling large amounts of data storage, and have standard features such as built-in touch screens and multimedia input and output capabilities. Several software applications for palmtop computers have been developed that target use by people with intellectual disabilities and other cognitive disabilities to promote increased independence in areas such as communication (Enkidu Labs, n.d.), schedule and time maintenance (Davies, Stock, & Wehmeyer, 2002a), and task completion and decision making (Davies, Stock, & Wehmeyer, 2002b, 2004; Riffel et al., 2005).

In common with desktop, notebook and tablet PCs, however, several features of mainstream palmtop hardware units create barriers to independent access by people with intellectual disabilities. First, the interface used for navigating among programs (e.g., launching programs, moving from one program to another) is complex, and although some graphics are used, the system largely depends on the ability of users to read. Additionally, due to the limited screen size, clickable items onscreen are much smaller than their desktop equivalents and therefore require the ability for very precise screen tapping with the stylus.

An additional barrier to palmtop computer use for this population is that these hardware units all come with an assortment of built-in physical buttons that, when pressed, launch designated applications or initiate commands within the active application. These buttons can be inadvertently activated quite easily, requiring the user to comprehend the error and navigate back through the system to turn off the unintentionally launched program or otherwise return to the program that was being used. Another inherent barrier is in the power conservation features of these units. They are pre-programmed to automatically shut down after a designated period of non-use, generally between 1 and 5 minutes, as a means of conserving battery power. It can be difficult for the user to find the correct physical button to power the system back up. Additionally, this button is often recessed into the hardware unit, which presents additional access challenges. Other barriers to using palmtop computer devices relate to the typical software utilities found in palmtop computers, such as those that display phone numbers or addresses or adjust the system's speaker volume. These are largely inaccessible to individuals with intellectual disabilities due to the interface complexity and literacy requirements.

To address these issues, a simplified multimedia software system was developed and evaluated in terms of its ability to enhance independent access to portable palmtop computers by people with intellectual disabilities. The prototype system was designed to: (1) allow more independent navigation between different computer applications; (2) include specialised multimedia modules to make typical palmtop computer utilities (such as an address book or volume control) more independently accessible; and (3) investigate opportunities to reprogram embedded features of the hardware units to alleviate barriers and allow simplified functionality, for example by automating the process of ''locking out'' physical buttons on the hardware units, ''hiding'' the system's Start bar (which is used to launch programs in the mainstream operating system interface), or preventing units from automatically shutting down during periods of non-use. This system (called the Pocket Voyager) was developed as a software application that ''sits on top'' of the mainstream Pocket PC operating system to provide a simplified interface for accessing palmtop computer programs and features. The design of the interface was based on recommendations made in the literature (Davies et al., 2001; Okolo, Bahr, & Rieth, 1993; Wehmeyer et al., 2004) for ensuring ''cognitive accessibility'' in software design. Thus, the interface included clear, uncluttered screens; consistent commands and features from screen to screen; appropriate sequencing and pacing; examples and graphics; picture and audio feedback and prompts for navigation; sufficient practice opportunities; designs that maximise touch-screen effectiveness; use of error minimisation techniques; and customisation.

This paper reports a study designed to assess the capacity of the accessible interface system to enhance independent navigation between commonly used programs and features on Pocket PC palmtop computers by individuals with intellectual disabilities. The hypothesis was that the specially designed interface system would reduce the amount of assistance required by people with intellectual disabilities to navigate between a defined set of typical software features and the number of errors encountered in independent navigation.

Method

Participants

A total of 32 individuals with intellectual disabilities participated in the study. This number was determined based on the availability of participants, the time allotted for the study, and the selection criteria listed below. Participants were adults with intellectual disabilities (18 years or over) who were recruited through educational and adult service systems in a midwestern state of the USA. Specifically, participants were recruited through established professional contacts from a large school district (over 20,000 students) and from three different local and regional private non-profit organisations providing services to adults with intellectual disabilities. Criteria for participation included a primary diagnosis of intellectual disability together with demonstrated vision, hearing and motor skills sufficient to interact with the palmtop computer. Of the 32 participants, 17 were male and 15 were female. Ages of participants ranged from 18 to 54 years, with a mean age of 30.8 ($SD=12.1$). Full Scale IQ scores for the group were obtained from psychological evaluations on file and ranged from 24 to 76, with an average IQ score of 56.1 ($SD=12.3$). Informed consent was obtained from each individual and, when appropriate, from his or her legal guardian. Participants received an honorarium for their participation in the study.

Study design

The study utilised a within-subjects design (Campbell & Stanley, 1963) in which all participants participated in both control and experimental conditions. People with intellectual disabilities participating in the study received training on how to use two palmtop computer navigation systems, the standard Windows CE operating system and the specially designed Pocket Voyager interface, to navigate between several common programs and features of palmtop computers. The one-to-one training for each participant consisted of: (1) demonstration by a researcher of the sequence of palmtop computer tasks used in the study; and (2) trials of the sequence performed by the participant until he/she could perform the entire sequence once through under each condition with only verbal assistance. The complete sequence for each testing session is provided in Table 1. The navigation sequence included the same structured series of tasks for both the experimental and control conditions, and involved starting or navigating common applications and features on a palmtop computer. During study sessions, the order of presentation of the two systems was randomised to control for ordering effects. The Windows CE operating system

Table 1. Test session procedures

Step	Instruction	Notes/Result
1. Hands-on walk-through of first navigation system	Researcher provides directions on Steps 3–8 while volunteer operates system.	Volunteer successfully navigates between all six applications; is shown what each application is for and attempts to identify people on the Contacts list.
2. Begin Evaluation	Researcher informs volunteer that we will "go through it one more time", and that he or she can ask for help if needed.	Volunteer agrees.
3. Starting Microsoft Word	"First let's start Word."	Researcher to record prompts and errors as defined.
4. Changing Volume	"Now let's change the volume."	Researcher to record prompts and errors as defined.
5. Starting Pocket Coach	"Now start Pocket Coach."	Researcher to record prompts and errors as defined.
6. Starting Contacts	"Now let's look up phone numbers"	Researcher to record prompts and errors as defined.
7. Starting Solitaire	"Now start the card game Solitaire"	Researcher to record prompts and errors as defined.
8. Starting the Calculator	"Now the last one is to start the calculator"	Researcher to record prompts and errors as defined.
9. Repeat steps 1–8 with second navigation system	See above	See above

generally offers several ways to perform the same action (e.g., hardware buttons, Programs menu, Start bar). This interface was set up to require the least number of steps to start the six applications evaluated, while still maintaining an example of each of the methodologies used to start applications. Completing the navigation tasks required a total of 15 steps (screen taps or button presses) when using the mainstream Windows interface, while 17 steps were required to complete the same sequence of tasks when using the specialised interface.

Except for the address book application, no data were collected regarding the user's ability to work within the six applications that made up the study sequence. Following completion of training as described previously, participants were asked to "go through it one more time" with each system, and were advised that they could ask for help if needed. Thereafter for each session, the only prompt given was the initial instruction to, for instance, "start Word". These were not recorded as prompts for the purpose of data collection. During each session, the frequency of prompts and number of errors made during each trial were recorded. A prompt was defined as any verbal, gestural, or physical stimulus that guided the participant to perform the task in any way. These included direct verbal instructions (e.g., "You have to scroll down first to see it."), questions about the task ("What is the next step?"), gestures (pointing, eye gaze) toward materials, modelling the current or next step, and any level of physical assistance (touching hand to guide, providing hand-over-hand guidance). Measures of assistance needed were limited to a maximum of three prompts per step before test participants were physically assisted to the next step. Errors were recorded when participants made an input that moved away from the desired target; that is, neutral inputs (such as tapping a blank area on the screen) were not recorded as errors. When an error was made, participants were redirected to the appropriate sequence to avoid compound errors, and in these cases one error and one prompt were recorded. Each session therefore involved a participant completing the navigation sequence once through under each condition, and all individuals were able to complete the navigation sequences successfully with prompting as described above.

A final part of the study was designed to conduct a preliminary comparison of participants' ability to correctly identify people in the specialised multimedia address book prototype as compared to the Windows CE Contacts utility. For both systems, the same three contacts were entered into the respective systems, and users were asked to locate an individual and point to the correct phone number for the person.

Software design

The following provides a brief overview of the prototype system developed and evaluated in this project. First, the physical buttons on the front of the unit were programmed to redirect to the Pocket Voyager application when pressed, to avoid the potential for inadvertently starting other applications. Another requirement discovered during preliminary design evaluations was the need to develop a method to remove access to the controls on the Windows Start bar and at the bottom of the display (e.g., the onscreen keyboard) to reduce interface complexity, user confusion and the subsequent potential for getting "lost" in the system.

The system was developed to provide the capability to create customised, oversized multimedia buttons to launch applications and features on the palmtop computer. Icons on the main display – each representing a unique application – were oversized to reduce the need for precise tapping or clicking on the touch screen, thus allowing users to interact with the system by using their finger as opposed to using only a stylus. When one of these icons on the main display was tapped for the first time, a dual-purpose audio message played. This feature, referred to as "Button Talk," was designed to audibly identify the icon's purpose (i.e., to launch a designated application), as well as to cue the user as to how to proceed. For instance, tapping once on the "Word" icon played the following message: "If you want to start Word, tap here again." Tapping an icon twice *consecutively* would start the program. This feature also provided a training component, as users could tap different buttons once to help learn their function.

A simplified address book utility was also developed for evaluation in this study. The main features of the modified address book entry process involved a digital image of the contact for whom information was available, and a large-font phone number that was read aloud via a recorded audio file played through the unit's speaker. For the purposes of this study, the list of entries for both the Pocket Voyager address book application and the default Windows CE Contacts program were limited to three contacts to allow for an equitable assessment.

Data analysis

Once data collection was complete, the data were analysed using *SPSS PC+ for Windows*. A Sandler's A-statistic (a form of the Student's *t*-test) for paired samples was used to test for mean differences between the two palmtop computer navigation approaches. Mean differences in the two dependent measures were tested for significance at the .05 level.

Results

Table 2 provides results from the paired-sample *t*-tests. The average number of prompts or assistance needed for participants to complete the navigation sequence using the Pocket Voyager interface was 1.41, while the average need for assistance when using the mainstream Windows CE operating system was 5.34 ($t = -3.39$, $p < .001$). Similarly, participants made an average of only .78 errors when using the Pocket Voyager prototype, compared to an average of 3.22 errors made when using the mainstream interface ($t = -8.14$, $p < .001$).

Data were also collected on participants' ability to correctly point to the phone number of three different people in the address book applications of the two systems. Table 3 summarises these data for the address book task. Mean comparisons for statistical significance were not conducted due to the low number of entries on the address book lists. (In all likelihood, phone lists would contain significantly more than three entries at any given time.) Nevertheless, when using the mainstream Windows CE address book application, participants were able to correctly point to the requested phone number (requested by the person's name, e.g., "Can you point to Dan's phone number?") only 62.5% of the time, while 53.1% of the participants were able to correctly point to all three contacts on the list and 25% failed to get any correct. When using the modified address book utility, participants were able to correctly point out the requested phone number 93.8% of the time, while 78.1% of participants pointed out all three numbers correctly, and in all 32 cases, participants were able to get at least one correct.

Discussion

The results of this study provide preliminary evidence that palmtop computers can be made more independently accessible to people with intellectual disabilities through the use of programming methodologies and customisable multimedia software that adhere to features associated with cognitive accessibility. Users with intellectual disabilities were able to navigate with significantly greater independence between programs and features, and with significantly fewer errors, with the specialised interface. The relatively limited sample size and the restricted activities in which participants engaged should be considered as limitations when generalising findings.

Several barriers to accessing palmtop computer hardware units were identified and addressed during this project. Some of these barriers overlapped, as did the methodologies used to overcome them. One of the major barriers to access in the mainstream Windows CE operating system is its complexity. Mainstream software developers commonly provide

Table 2. Dependent variable data analysis results

Dependent variable	Pocket Voyager prototype interface	Windows CE interface	*t*-value
Number of prompts required to complete navigation sequence	Mean=1.41 (*SD*=1.94)	Mean=5.34 (*SD*=3.26)	−3.39*
Number of errors made	Mean=.78 (*SD*=1.86)	Mean=3.22 (*SD*=3.83)	−8.14*

*$p < .001$.

Table 3. Comparative data on address book utilities

Measure	Pocket Voyager prototype interface	Windows CE interface
Number of times participants able to correctly identify phone number (*N*=96)	Correct=90 (93.8%) Incorrect=6 (6.2%)	Correct=60 (62.5%) Incorrect=36 (37.5%)
Number of participants able to identify all three phone numbers correctly (*N*=32)	3 Correct=25/32 (78.1%) 0 Correct=0/32 (0%) 1 or 2 Correct=7/32 (21.9%)	3 Correct=17/32 (53.1%) 0 Correct=8/32 (25%) 1 or 2 Correct=7/32 (21.9%)

several different methods for accomplishing the same task, such as icons on the Windows Start bar, using the Programs menu, or using physical buttons on the hardware unit itself. Participants had difficulty remembering which format to use to correctly start the desired application in the mainstream environment. Ironically, a total of 15 steps were required to successfully complete the study sequence of launching six designated applications when using the Windows system, while 17 steps were required to start the same six applications in the specialised multimedia system. However, the variation in the 15 steps for the mainstream Pocket PC system proved to be a barrier, while the consistency and repetition of the 17 steps in the modified interface (press hardware button to start Pocket Voyager, tap icon to hear message, tap icon again) was instrumental in overcoming the additional steps required to start the six applications.

Another barrier to palmtop computer access arises from the need for mainstream technology developers to provide a feature-rich environment while limited to a very small screen interface. This results in extremely small clickable objects on the screen. Using these miniaturised buttons and links was a difficult or impossible task for many test participants. For example, several individuals exhibited varying degrees of hand tremors while attempting to use the mainstream interface. It was clearly evident that while these participants repeatedly made errors due to this physical condition, they knew exactly which control they were trying to tap. In several other cases where hand tremors were not evident, limitations in fine motor skills also created problems. This led to increased frustration for some participants who were observed making repeated unsuccessful attempts to tap the correct control on the screen before finally succeeding.

This barrier was addressed by providing large clickable areas for the six applications in the evaluation sequence. Specialised multimedia onscreen buttons were over ½" square, and all study participants were able to effectively utilise these buttons. Even those participants with hand tremors were able to accurately use this feature, sometimes with their fingers. Due to the minuteness of clickable areas in the mainstream environment, use of a finger to make selections was ineffective and, at times, impossible.

A third major barrier was that button icons by themselves did not provide enough information to participants to enable independent program identification. In these cases, non-readers were consistently unable to correctly identify the text that accompanied icons in most parts of the Windows interface. The Pocket Voyager interface addressed this problem with the use of an error minimisation featured termed "Button Talk," where a customised audio message identified the application represented by the icon, and additionally provided a cue on how to proceed. The custom-recorded button talk message was played when the button was clicked once; consecutive clicks served to launch the application (e.g., "Click here again if you want to start Word").

Another example of a barrier identified during the study was the use of a small, vertical scroll bar in the mainstream interface. Many participants failed to understand the presence of the scroll bar when the desired icon was not immediately visible on the screen, even after the orientation training was conducted. This was further complicated by the small size of the scroll arrows and the narrow scroll bar. Several methodologies were available to overcome barriers related to using scroll bars in the Windows CE 2002 operating system used in the study (the most up-to-date version available at the time). For example, an interface that has been used successfully in desktop applications uses an onscreen, talking "Next" button to move to successive arrays of clickable icons.

The presence and function of the physical buttons on the hardware units provided another barrier to access for people with intellectual disabilities. These buttons are defaulted in the mainstream operating system environment to launch designated applications, such as the address book or daily schedule. Although they can be reprogrammed to launch other applications, the current version of the Windows CE operating system used in the study requires that: (1) each button be assigned to *some* application; and (2) each button must point to a *different* application. Although this was not necessarily a problem in the controlled situation of the pilot study, where participants were being directed to perform specific tasks in a sequence, previous field-testing with palmtop computers by the research team has suggested that these buttons can cause confusion when pressed either unintentionally or out of curiosity. The potential for misuse of physical buttons on the hardware units was remedied by writing computer code that automatically redirected the hardware buttons to the Pocket Voyager interface, with the net effect that pressing any button would either: (1) launch Pocket Voyager if it was not already running; (2) return to Pocket Voyager if it was running but was not the active application; or (3) remain in Pocket Voyager if it was running and was the active application.

During the study, several applications common to palmtop computers were identified as introducing additional barriers to palmtop use by people with intellectual disabilities. A specific example explored in this study was an application commonly known as Contacts. Contacts (or address book) applications generally allow users to record information about individuals and organisations, such as phone numbers, addresses, job titles, email addresses, and other notations. Mainstream contacts applications usually provide a listing of entries in alphabetical order that show limited information. When the user taps one of these entries, more information is displayed, at which point scrolling or further tapping may be necessary to view the desired information. During the pilot study, only three entries were made on the Windows CE and Pocket Voyager contacts lists. However, despite having to choose from only three entries, participants with intellectual disabilities were only able to correctly identify entries on the mainstream contacts list about two-thirds of the time. These same participants accurately identified entries in the Pocket Voyager address book list over 93% of the time, thus demonstrating the utility of using multimedia to make this task more accessible. One participant, upon successfully identifying the three contacts in the multimedia address book, exclaimed: "I like the pictures, I should put my friends in there!"

Other common palmtop computer applications and features were identified that would be important to address in further similar research to improve accessibility for people with intellectual disabilities. Examples of these include a simplified voice recorder to allow non-readers to make spontaneous notes; easier access to system controls such as changing speaker volume or checking battery power; more accessible scrolling mechanisms; art or drawing applications; a simplified word processor; an image-capture utility to capture onscreen handwriting that is not of high enough quality for automatic character recognition; and more accessible/simplified versions of the calculator, audio player and e-reader utilities.

This study evaluated the utility of a particular modification to the operating system and one application of palmtop PCs, but is more important for the fact that it illustrates the benefits of using modifications to mainstream software technology, particularly palmtop PCs, to provide supports for people with intellectual disabilities. Palmtop PCs are relatively inexpensive, portable, and increasingly more powerful. As palmtop technology merges with digital telephony, Internet and other technologies, palmtop platforms will provide even more opportunities to provide supports to this population. While it would be preferable if manufacturers were to take some of these design features into consideration to make mainstream devices more accessible for more people (and this should be a focus of advocacy), it is likely that any platform will need customisation or configuration to meet the unique needs of individuals with intellectual disabilities. The Pocket Voyager software is one example of how software can be developed that enables people to use these devices. This research provides support for the contention that a single palmtop PC could be a useful platform for providing a wide array of supports for people with intellectual disabilities, from serving as an augmentative communication device, to providing workplace prompting or independent living supports, if the barrier of the inaccessibility of the operating system is able to be addressed.

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