Making the Computer Accessible to Mentally Retarded Adults

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Little research has been conducted on how to teach computer skills to developmentally disabled adults. A head counselor at a home for mentally retarded adults, who served as the inspiration for this article, was an enthusiastic personal computer user who tried to share computer instruction with home residents. Efforts at using commercial applications designed for young children were unsuccessful. Residents briefly watched the counselor use the applications, then lost interest. Staff members had neither the time nor the user interface background to investigate which applications and user interaction design factors might make computers accessible to home residents. In this article, we describe our empirical investigation of computer use among moderately developmentally disabled individuals. We investigated the input devices preferred, and the user interaction design issues to be considered when designing or selecting applications for this population.

Most research on computer use by the mentally retarded falls into two general categories: Computer science literature discusses advanced assistive technologies, such as eye-blink technologies and speech synthesizers, but does not address usability of commonly available devices for mentally retarded persons without severe physical limitations. Education and psychology literature describes use of computer technology in special education settings, focusing on teaching techniques rather than usability factors.

Review of more than 500 references found by a Dialog search suggests that while computer applications have great potential as teaching tools for the developmentally disabled, computer science practitioners aren't exactly rushing to provide these specialized applications. Bull et al. evaluated use of computer-assisted instruction to improve mentally retarded individuals' language skills, recommending development of learner-based applications for this group and suggesting the computer be used by students and instructors in a shared context [2]. Strommer et al. found that including images along with object names improved retention when using computers to teach spelling to mentally retarded children [9]. Briggs et al. used a self-paced computer program to teach behavioral skills to moderately retarded adolescents [1].

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Hagen provided guidelines for selecting educational applications using adaptive devices for students with physically handicapping conditions [5].

Two studies suggested possible user interaction paradigms that might be successful with mentally retarded adults. Fazio and Rieth found that a game approach might enhance computer usability and learning for our target population [3]. Observation of a classroom of retarded 3-to-5-year-olds found the preschoolers rejected rote learning drills, preferring games with excellent graphics. Horner et al. compared a high-efficiency approach requiring a simple response (pointing to an object on the screen) to a low-efficiency approach involving greater interaction. Their 14-year-old mentally handicapped study participant preferred the low-efficiency/high-interaction approach [6].

Interviews with professionals in the developmental disabilities field, including counselors at community living organizations in Arlington and Fairfax counties in Virginia, and a representative from the Virginia Department of Rehabilitative Services, confirmed that user interaction design requirements for our target population have been little studied. The State of Virginia Assistive Technologies database listed 20 computer-based instruction programs for students with "auditory handicaps, visual handicaps, and mild mental retardation." No usability data was given for any of these programs. We made similar observations upon surveying materials in the Fairfax County Schools Audio/Visual Laboratory and Special Education Resource Center. Descriptions of applications dealing with vocational or life skills, such as maintaining a checkbook, focused on educational content and gave little information on the user interface.

Experimental Design

Teaching developmentally disabled individuals presents special challenges. The first author volunteered in group homes sponsored by Virginia Community Residences Incorporated (CRI), a social services agency providing housing and support services to mentally disabled adults. Counselors used a combination of simulation and field trip training to develop such skills as paying for purchases, taking the bus, and dressing appropriately. Many residents had moderate to poor retention, especially of less frequently used skills such as handling money. Training was repeated often, and counselors continually searched for teaching tools to assist in this task.

Our empirical investigation had three goals: to investigate the feasibility of using a personal computer with adults diagnosed as moderately mentally retarded, to determine which input devices were best for this population, and to produce user interaction design guidelines to help those developing or purchasing applications for this population. Because we found no other usability studies conducted with our target population, we used a three-phase approach, with results of each phase informing the next.

In phase I, we observed 12 computer novices use a computer with two input devices (touch screen and mouse) and a graphical user interface (GUI). In phase II we built on phase I observations, conducting a usability evaluation of three input devices (mouse, touch screen, and trackball) and producing user interaction design guidelines. In phase III, we used our guidelines from phase II to develop and evaluate an interactive prototype consisting of two games: Shopping, to teach money handling, and Getting Dressed, to reinforce selection of work clothes.

The study used equipment a community-based program could expect to acquire through purchase or donation. Eye-blink technologies and other high-cost assistive devices were beyond our scope. The machine, donated by local businesses, was a Dell 386SX microcomputer equipped with MS-DOS 5.0, Windows 3.1, 8 MB RAM memory, a 200 MB hard drive, and a Microsoft mouse. A clip-on analog capacitive touch screen frame and controller were used because the vendor provided an easy-to-use calibration utility. Phase II used a Kensington trackball, an oversized trackball frequently used to improve accessibility for physically handicapped persons.

Participants were men and women aged 25 to 60 living in homes sponsored by CRI. All had been professionally evaluated as moderately developmentally retarded with widely varied functional abilities. Some held jobs in commercial organizations; for others, sheltered workshop employment was more suitable. CRI counselors recommended selecting participants who showed strong emotional stability, ability to follow directions, and an outgoing attitude. When asked if they had played computer or arcade games, two women participants reported that such games were "too loud," "too violent," and "don't look like fun." One male said they "cost too much money." The counselor explained he did not have the eye-hand coordination necessary to prolong the action and quickly lost his quarters.

Phase I

In Phase I, studies were conducted in a quiet but cramped counselor's office. We initially used a tape recorder to collect comments, but found participants focused on the recorder to the exclusion of the computer. Evaluation sheets proved the least obtrusive data collection instrument. An experimenter sat behind the participant and held the stopwatch low for unobtrusive timing. Phase I used four men and eight women. Each session began with a children's game called KidSmarts Shapes and Colors, in which a user creates simple pictures by using drag-drop to move triangles, rectangles, and circles. This application was selected because CRI counselors classified the participant population as having extremely limited reading ability (most can read only their own name), and widely varying speech proficiency and eye-hand coordination. Participants moved icons using both a touch screen and a mouse. We collected mostly qualitative data, as our goal in this phase was to determine participants' ability to use mouse and/or touch screen, and to determine what problems they experienced with GUI use.

Initial reaction to the Shapes and Colors game was negative. Only one participant, an older woman, completed a picture. Two started the game, and then said it "wasn't fun." One did not even wish to try. The experiment team switched to the Solitaire game provided with Windows. Participants immediately recognized this as "playing cards" and began attempting to use the mouse and touch screen. Because participants had difficulty remembering which mouse button to click and did not have the dexterity to easily double-click, we placed red stick-on dots on the left mouse button and on the ENTER key. This enabled the experiment team to give instructions such as "click the red dot," "click the red dot twice" or "press the red dot on the keyboard." Participants used the touch screen fairly easily, but found it "tiring."

During this phase we made the following observations:

- Participants were startled by unexpected or unintended icon movement. For example, they were reluctant to continue if an accidental click turned a card. The

experimenter had to continually reassure participants that the computer would not break.
- Participants often resized the window unintentionally, a major cause of frustration.
- The "file" option on the menu bar was often accidentally activated when a participant attempted to click on the card deck to turn cards. Participants seemed unaware of words on the menu bar.
- Single clicking posed no problems, but double clicking was extremely difficult. Even with a red dot affixed to the left mouse button, participants did not grasp the concept. We therefore began using a single click for selecting items and instructed participants to use the ENTER key for double clicking.
- Participants were delighted when the pattern on the back of the card deck changed with each deal, commenting positively on the attractive visual cues.
- As the number of cards exposed on the screen increased, participants took longer to react and make correct drag-drop movements.
- Computer use was seen as a group activity. Participants became upset when we excluded friends from sessions. We compromised by allowing five people around the computer (participant, two friends, experiment team member giving instructions, and experiment team member recording times and observations). At the time, we considered the group situation a nuisance, but it would turn out to be a significant finding.

Phase II

In Phases II and III, studies were conducted in a corner of a large living/dining room area. Although noisier, lighting was better, the workstation was not cramped, and participants were more relaxed. Three Phase I participants had severe motor or visual problems that affected computer use, and a participant over 60 declined further participation. Phase II focused on input device usability with the remaining four men and four women. The computer was equipped with a touch screen, a mouse, and a Kensington trackball, presented in counterbalanced order. Experiment software was again Solitaire. Quantitative data included time to drag-drop a designated icon to a target area (averaged over five trials for each device). Qualitative data collected included device-related movement problems, screen navigation problems, and subjective user satisfaction (determined from participant comments). Based on our Phase I experience, we reduced Phase II session time to about 10 minutes per device (a total of 30 minutes with rest breaks).

Some participants had an aversion to the stopwatch and would begin random movements when they glimpsed it. We kept the stopwatch as concealed if possible, and factored random data out of our results. Table 1 summarizes drag-drop times and preferences for the three devices. The touch screen had the fastest and the most consistent times and the trackball had the slowest. No statistical analyses were performed because of the small number of participants and other uncontrollable variants among participants.

Although the mouse did not yield the best average time, it was preferred by the largest number of participants (four). Participants were fascinated that mouse movement caused cursor movement, although their fascination diminished somewhat after a familiarization period. Six participants engaged in free play experimentation with the mouse after three or four timed moves. The trackball was more difficult to use and did not inspire this type of experimentation. All participants used both hands to

Table 1. Summary of device evaluations.

	Mouse	Trackball	Touch-screen
Participant preference* (device "liked best")	4	1	1
Average Drag-Drop Times	9.9 sec	12.3 sec	4.9 sec
Std. Dev.	7.0 sec	18.5 sec	3.9 sec

*** Two participants had no preference among devices.**

perform a drag-drop with the trackball, one hand depressing the left button, the other rolling the ball. Except for one participant, all found the touch screen "tiring" or "not fun."

To compare participant use of the mouse with non-developmentally handicapped individuals, we took control measurements with Solitaire. Control participants were a 23-year-old computer scientist with extensive mouse experience, a young woman with some mouse experience, and a middle-aged man with little mouse experience. The controls were much faster mouse users than the study participants. Average control times across five measurements were 2.4, 3.2, and 3.2 seconds, respectively. Home residents, by contrast, reacted in a slow, deliberate manner and moved icons with measured, carefully controlled gestures. Fast action is not an application requirement for our target population.

Usability problems encountered during Phase I continued to arise in Phase II. Participants accidentally resized windows and unintentionally activated the menu bar, especially the pull-down menu for the "file" option.

During the four months between Phases II and III, the computer was used recreationally by participants, other residents, and developmentally disabled visitors. Solitaire was the most consistently popular game. Two shareware programs—simple versions of Hangman and Wheel of Fortune—were also popular and helped teach letters and words. Action-based children's games were rejected by residents. Games requiring users to evade hostile attacks were the least liked. Because of their slow reaction times, participants were wiped out in minutes. A preschool game featuring bears getting dressed, brushing teeth, and so on was also installed. Residents thought the bears were cute, but were insulted when counselors attempted to draw parallels.

During this period, two distinct user groups emerged. Individuals who tested at the upper level of the moderately developmentally disabled range showed mastery of the computer and learned to use both mouse and touch screen. A second group, more severely handicapped, had problems expressing themselves verbally and found strange situations frightening. However, in the security of their home with people they knew, they wanted to try the games. The more severely disabled became touch screen users and wanted to play games, especially Solitaire, with counselor assistance. When the disabled individual used the touch screen and the counselor used the mouse, the computer provided a nonthreatening shared experience that encouraged conversation, helped improve verbal skills, and provided an interactive activity that drew observers. The head counselor considered this a valuable contribution to the home because a major goal was to encourage appropriate social interaction.

Phase III

When Phase III began, six of the previous participants were available, three men and three women. We used the prototype with only the mouse to focus on the usability of the screen design. Using guidelines produced in Phase II, and based on findings from Matson and Long [7], we developed a Visual Basic prototype of two games based on living skills taught in the group home: managing small amounts of spending money and dressing appropriately for work. Because some residents had been taken advantage of when shopping alone in the community, counselors spent many hours trying to relate printed numbers, as on price tags, to actual coins and bills. Some residents also had problems selecting clothing for work and putting dirty clothes in the laundry at the end of the day. The first prototype game, called Shopping, enabled users to select and purchase items with icons of dollars, quarters, and dimes. The second game, called Getting Dressed, was designed for individuals with limited basic living skills. It used a drag-drop paradigm to dress a screen outline of a person with items of clothing, or put dirty clothes into a laundry basket. Because Phases I and II participants often became discouraged by challenges at the start of a session, Phase III participants played the less complex Getting Dressed first. Features of both games included:

- Strong visual cues to indicate items such as appropriate clothing and a laundry hamper.
- Photographs or realistic drawings, which were used since cartoons and abstractions (such as a rectangle with "$1" on it) were not easily recognized.
- Minimal screen items, since acceptance of a game decreased as screens became more complex.
- Logical and realistic icons grouping. Dollar bills were overlapped and prices were placed over pictures to provide visual groupings. Clothing was deliberately scattered to create a situation requiring more thought and more closely simulating the real world.

Shopping screen 1 required major revisions to achieve usability for the intended population. Shopping's initial screen 1 design (see Figure 1) displayed six items costing less than $10, the amount generally available to participants for discretionary spending. When the PRESS TO PAY button was clicked, screen 2 presented money icons, a box showing COST of purchase, and a PAID box that reflected money icons moved to the PAY HERE area. When a participant clicked to buy an item, its price tag changed from white to green, which was too subtle. The redesigned screen added a shopping cart to which participants could drag items intended for purchase (see Figure 2). Also, 12 dollar sign ($) icons were added, which decreased as purchases were made and increased when items were replaced. Screen 2 was also redesigned (see Figure 3), to more logically group dimes and quarters. Figure 4 shows the appearance of

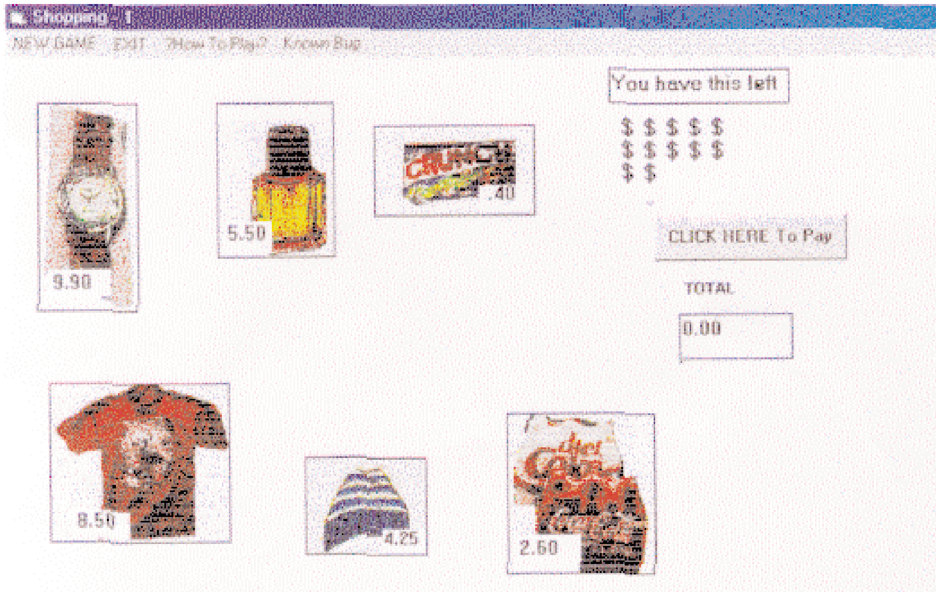

Figure 1. Initial screen 1 design for Shopping.

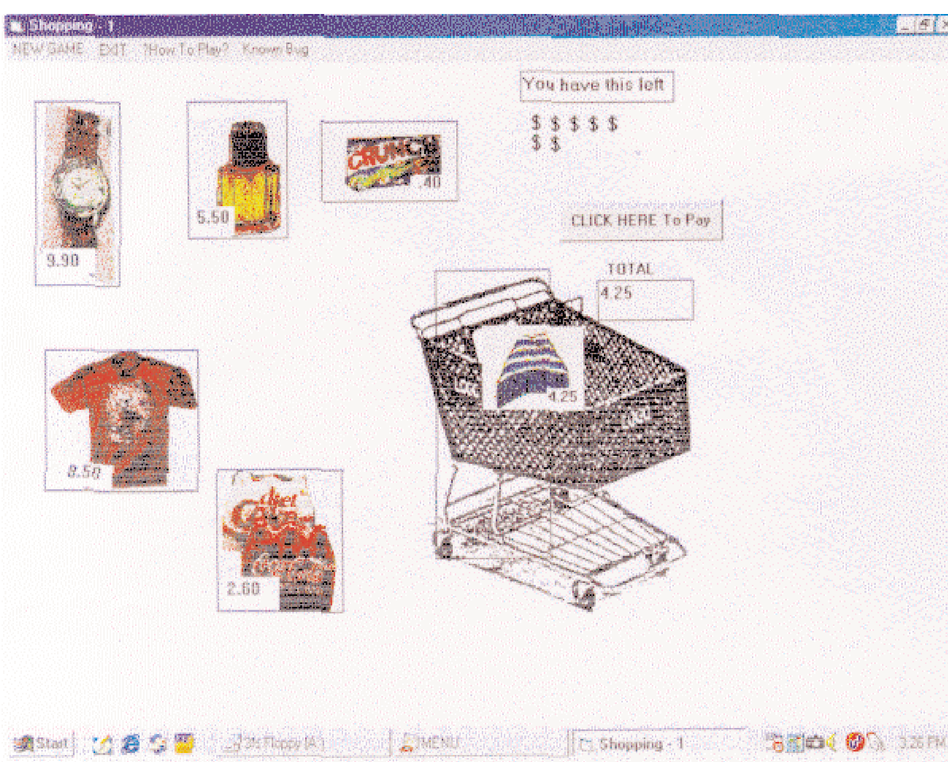

Figure 2. Redesigned screen 1 of Shopping.

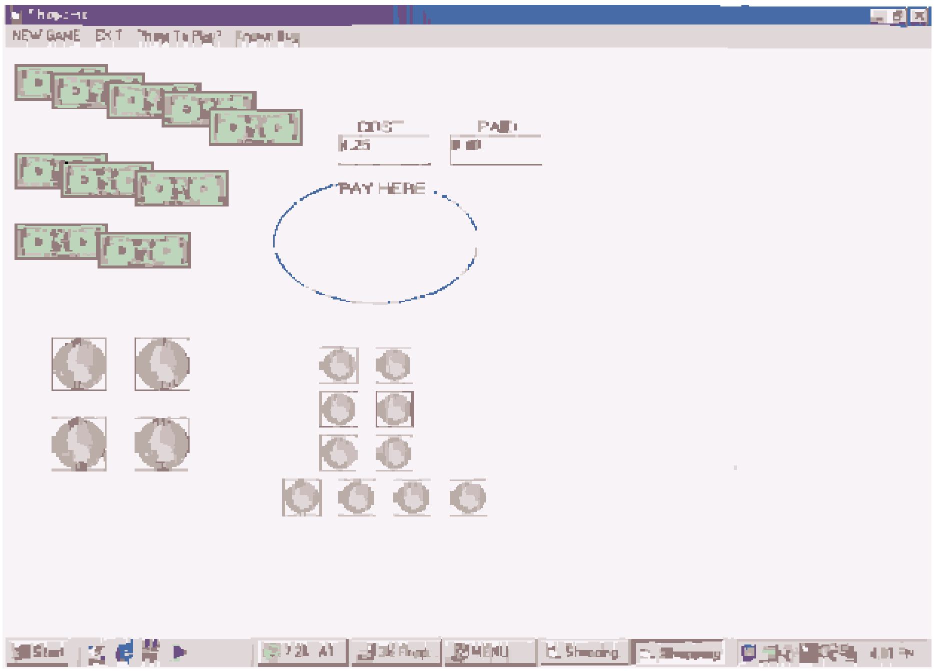

Figure 3. Redesigned screen 2 design of Shopping.

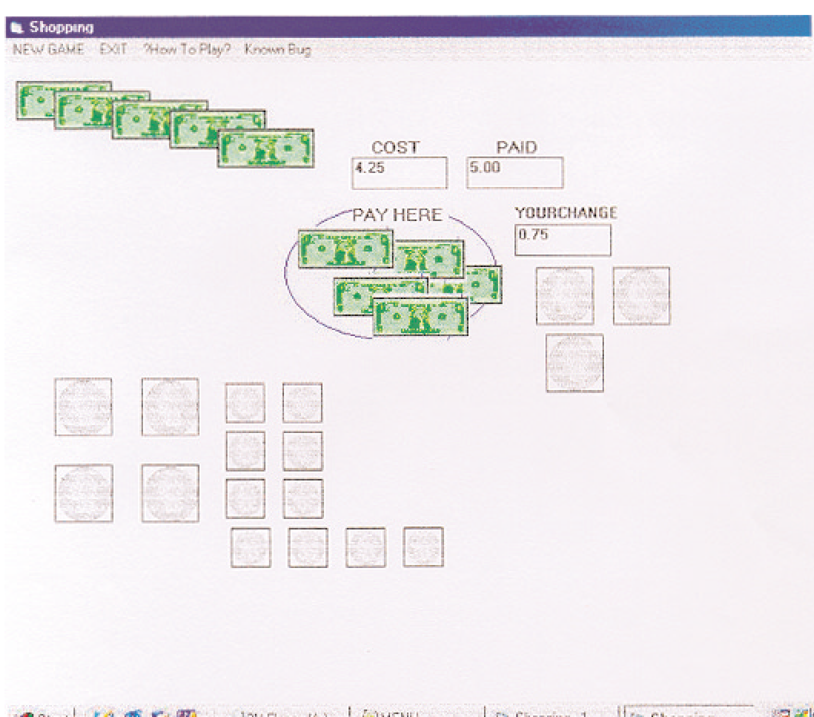

Figure 4. Screen 2 of Shopping after change returned.

Screen 2 after a purchase has been made and change returned. Participants said the redesigned Shopping Screen 1 was "more fun." Participants smiled as they moved items into and out of the shopping cart and quickly related appearing and disappearing dollar signs to the concept of "having money left." When dollar signs decreased to one or two, participants clicked to go to the payment screen without prompting, unlike the initial version where all had needed help to move to the payment screen.

Quantitative data collected included time to move item of clothing to outline of person and to move money icon to payment area, as well as number of items bought and number of icons moved before participant declared "game over." Qualitative data included reaction to game, menu item selected to start new game, ability to undo actions using PUT BACK, and screen navigation. Again, a statistical approach to data analysis was not appropriate because of the small number of participants and the variety of non-user interface factors that impacted recorded times. Phase III focused on several user interaction design factors:

Icon size and visual effect. Participants had problems with icons that were too large as well as too small. Games with large icons sometimes caused confusion as participants tried to figure out where to click. Icons in Shopping varied from 2 by 2 inches (tee-shirt) to 0.5 by 0.5 inch (dime). All could be activated from any point within the picture area. In Shopping, participants easily placed the cursor on the dial of the watch (1 by 2 inches). However, when we suggested they might like to select the tee shirt, they would move the cursor in a random manner, then go to another picture with a strong graphical element that provided a good target, such as a cap on perfume bottle, or a Coca-Cola logo.

Icon arrangement. The $1-bill icons were 1 by 0.5 inch, overlapped in stacks containing five, three, or two bills. In the original design, the four quarter icons were 1 by 1 inch and arranged in a row. Ten dime icons were 0.5 by 0.5 inch, arranged in two rows of four each and one row of two. Dollar and quarter icons were easily manipulated. However, participants hesitated moving a dime, suggesting this icon layout did not seem to offer an easy entry point. The screen was redesigned (as shown in Figure 3) to show three rows each with two dimes and a bottom row of four dimes. Participants then easily moved the top two dimes, and worked their way down the stack, moving icons by positioning the cursor on the image of a head in the center of the icon.

Icon grouping. In Getting Dressed, participants began with icons closest to the target—either the person or the hamper. Similarly in Shopping, participants began with a coin icon closest to the payment area. The redesigned screen in Figure 3 had a definite top-to-bottom appearance that significantly reduced confusion.

Icon spacing. In Getting Dressed, icons were arranged randomly with spacing ranging from 0.5 inch to 1 inch. Participants had no problem with 0.5 inch spacing when closely spaced icons had large selection areas, such as the 0.75 by 1.5 inches pants, which were 0.5 inch from the 2 by 2 inch tee shirt. However, experience with Solitaire showed that spacing less than 0.5 inch did cause problems if the selection area was small, such as for the base card in a Solitaire stack (0.25 by 1 inch). Participants often required multiple attempts before positioning the cursor correctly to move a stack. Fully revealed cards, which were manipulated easily, were 1 by 1.25 inches. Further, accidental activation of the menu bar, particularly the "file" option (because it was only about 0.5 inch from an active screen area), frequently startled and disturbed participants.

Selection method. Participants preferred drag-drop to clicking. A major problem with the initial version of Shopping was that participants did not feel they had selected an item by clicking on it. They clicked multiple times to try to get the icon to "do something." The revised screen used drag-drop to move a chosen item into and out of a shopping cart.

Screen design. Participants encountered difficulties when drag-drop movements had to circumvent other screen icons. Lack of screen clutter and a logical, open path of movement proved more important than direction of movement. The ideal screen design allowed participants to drag-drop directly from top to bottom or left to right.

Menu bar. The words HELP, PLAY AGAIN, and EXIT were used on the prototype's menu bar. EXIT is a survival word taught to this group and is recognized on signs in buildings, but interestingly, this learning did not transfer to the computer screen. Most participants paid attention to words only when directed to look at them or when the words had some visually appealing characteristic (such as the distinctive Coca-Cola trademark). The concept of the menu bar had to be explained for each screen.

Screen navigation. In the initial prototype, participants had difficulty navigating from the shopping screen to the payment screen. Every participant had to be assisted in moving between the two.

Action. Participants were deliberate and wanted user-paced action that gave them time to think about their movements. They were startled when the screen reacted too quickly or when too many actions occurred in rapid succession.

Icon recognition. Abstract thinking is difficult for this population, so participants related better to the photographic images found in Shopping than they did to cartoon-like icons.

Social interaction. Games were initially intended for use by one person, and the initial design incorporated the type of "correct/incorrect" answer feedback found in instructional programs. When it became obvious two or more people would play these games, we abandoned the multi-screen, go-to-the-next-question paradigm. Rather, both games were designed to create a situation to be discussed by two or more people—the shared context.

Design Guidelines

Based on our results, we developed user interaction design guidelines, which are shown in Table 2. They fall loosely into three categories: physical (motor) considerations, mental (cognitive) considerations, and psychosocial considerations. All users benefit from strong, simple design, as the success of the Windows desktop metaphor illustrates, but for mentally retarded users good design is crucial. These individuals cannot easily make the necessary cognitive associations from a sketch of a shopping cart, for example, and need a photo realistic image. Similarly, they need to engage in realistic actions, such as drag-dropping items rather than simply clicking on them.

Additional Observations

Counselors observed improved participant number-matching skills as a result of playing Solitaire. Initially, participants had to be prompted to put "a red 6 on a black 7." At the conclusion of Phase I, participants recognized alternating red and black cards, but did not grasp ascending and descending number sequences. By Phase III, both descending and ascending sequences had been mastered. Also, the commercial appli-

Table 2. User interaction design guidelines and their rationale.

GUIDELINES BASED ON PHYSICAL CONSIDERATIONS	*RATIONALE*
Pace of screen action should be completely under user control.	Users have strong need to maintain control of computer and find sudden or unexpected movement startling.
Screen boundaries should be locked in place instead of using a design that allows user-resizing of windows.	Accidental or unexpected changes in size are confusing.
Active screen areas should be at least 1.5 inches away from the menu bar.	Accidental activation of menu options is confusing.
Pull down menus are not easily understood and used by this population.	This results from both motor control and cognitive problems.
GUIDELINES BASED ON MENTAL CONSIDERATIONS	*RATIONALE*
Very simple words can be used, but words combined with an icon are more quickly and better understood.	Meaning of icons must be taught. Icons (e.g., cart for "Shopping," figure of person for "Getting Dressed") were recognized correctly after familiarization session. However, use of question mark for help had no meaning.
User actions should mimic real life situations, especially using direct manipulation.	Moving items to shopping cart with drag-drop movement was more readily understood than clicking to select items.
Leave a clear path for movement of icons around on the screen.	This is essential for comprehension and manipulation without frustration.
Minimize use of icons and other screen clutter.	Large numbers of icons on a screen confuse and distract.
If the screen must contain a large number of items, use a logical grouping to assist understanding.	Large numbers of randomly placed icons is beyond normal comprehension for this population.
Avoid abstract concepts; use concrete presentations (e.g., photographs rather than cartoons or sketches to represent objects) and functions (e.g., dragging item from shopping cart).	Concept of "put back" was not comprehended when participant clicked a button to subtract an item from accumulator. Concept was immediately understandable when participant moved an item out of cart.
GUIDELINES BASED ON PSYCHO-SOCIAL CONSIDERATIONS	*RATIONALE*
Use the computer as a shared activity for this population, rather than as a stand-alone computer-assisted instructional program.	Designs that make an application fun for counselor or volunteer to use with target population will enhance mutual enjoyment, effectiveness, and usability of application.

cations brought in by counselors described earlier proved a welcome alternative to watching television. During a series of blizzards that kept residents housebound for almost two weeks, interaction fostered by the games helped ease tension and boredom. Games with learning potential helped both residents and counselors feel that productive use was made of this time.

The head counselor was concerned about the impact on individual self esteem if the experimental design encouraged randomized success or failure. Fortunately, these concerns dovetailed well with accepted usability evaluation practice: the computer was being evaluated, not the user. Participants exhibited pride as they learned to use the computer, which they recognize as an important tool in our society. One participant attended sessions in a shirt and tie and viewed the experiment as his "computer lesson." Gardner and Bates [4] found students felt they "learned more" when they used computers, and showed increased feelings of confidence and self-esteem, suggesting that computer use can counteract negative attitudes mentally handicapped individuals often encounter. CRI participants showed enthusiasm for the sessions and proudly reported their computer usage to persons at places of employment.

Conclusion

We found that adults with moderate developmental disability benefit from computer use when applications are appropriately chosen for this population. Further, we empirically determined user interaction design guidelines for selection or development of applications to make the computer accessible to mentally retarded adults. The value of computer applications as teaching tools for the mentally retarded appears to lie in how they promote interaction between participants and teachers—participants did not want to sit alone in front of the screen communicating with cyberspace. Also, computer applications for the developmentally disabled must be well-designed. The design guidelines developed from this study follow screen design principles well understood by user interaction design practitioners: uncluttered screens, grouping of elements, clearly defined navigational paths, use of real-world analogies, elimination of sudden startling screen changes, and appropriate icon spacing. But while these guidelines are important for the general population, they are essential for the population studied here.

Our findings could lead to studies with larger groups of mentally disabled adolescents and adults to investigate variables that impact computer usability. Because of the exploratory nature of this work, it proceeded at an extremely basic level. The next step should consist of a carefully worked out plan with experimental treatment conditions focusing on particular interaction conditions. We hope this study will encourage application developers to consider further research into design of applications appropriate for this population, many of whom work in janitorial jobs involving hazardous chemicals. Teaching tools are needed to cover safe handling of toxic materials, first aid, and similar work-related topics. Food handling safety is another possible area for application development, because many community-based organizations place their clients in food service occupations. Commercial training applications that take advantage of multi-media and GUI designs could have large potential benefits, but will likely be ineffective if not developed according to appropriate interaction design guidelines such as those produced by this study.

On December 20, 1971, the United National General Assembly adopted a Declaration on the Rights of Mentally Retarded Persons, which states in part [8]: "The mentally retarded person has a right to ... perform productive work or to engage in any other meaningful occupation to the fullest possible extent of his capabilities." In today's world, productive work often involves computer use. The findings of this study show that the mentally retarded can learn to use the computer. The developmentally disabled need not be left by the side of the road as our society builds the information highway.

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