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SpeechWare

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SpeechWare

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Version 1.0
2/6/89

SpeechWare

The manual for these stacks are in HyperCard format located on Disk 2. The SpeechWare Manual stack is intended as a "start-up" introduction to the use of the developer's edition stacks and simple customization of SpeechWare ProsthesisWare. In addition, the SpeechWare Manual contains a section on the Clinical Issues of the Macintosh in the field of Neuropsychology.

These disks are delivered without a System Folder. You will need to supply a System Folder or transfer the SpeechWare stacks to a hard drive. For the Macintosh Plus, Macintosh SE, & Macintosh II, use Finder v6.0 and System v4.2 or greater. If you need to run the stacks from floppy disks, place the System Folder and HyperCard on one disk and place each of the SpeechWare folders on separate disks.

These stacks were developed with HyperCard version1.1. You must have version 1.1 or greater and the Home stack. SpeechWare V1.0 C2.0 and SpeechWare V1.0 C3.0 refer to HyperCard's DateBook stack and these should be available. The Help stack should be available if you plan on modifying the stacks. Keep all SpeechWare stacks in their respective folders and you can retitle folders to suit. Before attempting to modify the stacks be familiar with the HyperCard Manual.

These stacks require MacinTalk which is supplied on Disk 1. MacinTalk must be in your System Folder to function. An external amplifier and speaker are useful for better volume control.

The SpeechWare stacks supplied on Disk 1 have background shading patterns to improve the visual appearance of function groups. With this shading it makes customization and modification more awkward. Disk 2 contains a developers edition without the shading. Use copies of these to modify the stacks for your patient's needs.

There are two stacks in the SpeechWare V1.0 C1.0 folder labeled Organizer and Copy of Organizer. The Organizer as delivered does not contain any dates. The Setup card on SpeechWare V1.0 C1.0 allows you to set the date you wish the Organizer calender to start at. After Setup is executed, the Organizer will then contain dates for a 26 week period. The Copy of Organizer stack is provided as a blank template so you can create a new Organizer at the end of each 26 week period. Make a copy of this stack and rename the copy "Organizer" before you create another 26 week Organizer from the Setup card in SpeechWare V1.0 C1.0.

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ProsthesisWare: A New Class of Software Supporting the Activities of Daily Living

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Abstract *To use the microcomputer as a prosthetic tool in rehabilitation has a number of advantages over using it as a tutor for cognitive retraining. As a tool, the microcomputer program directly addresses ecologically relevant issues in activities of daily living. New classes of software like HyperCard™ and MacLaboratory Controller©. can be readily customized for each patient's needs. Unlike tutors used for cognitive retraining, rehabilitation tools provide prosthetic support that does not presuppose any required reorganization or restructuring of damaged neural tissue. As this new approach to using microcomputers in rehabilitation is implemented, new types and styles of neuropsychological assessment will need to evolve, especially to provide sequential monitoring for adjustments to various iterations of the computer programs. We used the Macintosh™ computer with ProsthesisWare tools written in HyperCard for its ease and speed of design. The standard user interface relieves a patient's memory overburden by providing external function and sequencing cues. We present the case of Cecelia R., a patient with an expressive aphasia secondary to a traumatic brain injury. The development of successive approximations of a speech prosthesis for her—SpeakEasy©, SpeakEasier©, and SpeakEasiest©—illustrates how new hardware and software capabilities permit the rapid iterative design and redesign of cognitive prosthesis tools. This case also illustrates some limitations of the approach and new requirements that would be placed on the rehabilitation environment. We conclude that the emergence of ProsthesisWare constitutes a new application of microcomputers in rehabilitation that offers utilitarian prosthetic aids for the everyday activities of daily living for a select group of people with cognitive impairments.*

Keywords: Cognitive rehabilitation, aphasia, head injury, prosthesis, Macintosh computer, HyperCard.

Introduction

The past few years have seen an exponential increase in the use of microcomputers in physical and cognitive rehabilitation. Many functional applications and creative input devices have been designed for people with sensory or motor handicaps who are cognitively competent. On the other hand, the microcomputer has also been used as an aid for some elderly people who have a cognitive impairment or for people who have suffered a traumatic brain injury. The power and versatility of the microcomputer has been underutilized for such people, typically serving only in the role of a tutor, with the hope that repetitive drill and practice exercise would improve general cognitive capabilities like attention, concentration, and spatial and temporal relationships. At best, outcome studies show marginal results, particularly regarding generalizability to "ecologically valid" patient activities of daily living (ADL). Such tutoring software was often originally designed for grade school education or as games.

Our purpose in this paper is to explore the reasons why this limiting and unsuccessful approach employing the microcomputer as a tutor persists and to outline an alternative strategy, namely the microcomputer as a tool in rehabilitation. Our objective is not to change the patient, but rather to change the software. For illustration, we present a new class of rehabilitation software, ProsthesisWare, that functions as a prosthetic tool. General considerations of design and customization will be drawn from the case of "Cecelia R." and other traumatic brain injury patients in the research program. Figure 1 illustrates types of both tutor and tool applications for microcomputers in rehabilitation and the theory of ADL with which each has been linked.

As a tool the computer performs prosthetic functions individualized to the ecological requirements of each patient. Our project has provided for basic research on interface design for the cognitively impaired and for applied research on prosthetic applications for the traumatically brain injured patient. The relationship between a university and a major rehabilitation facility was necessary in order to provide the resources required for initial development. In our particular case the university supplied the computer support infrastructure and experience with psychological programming (Chute and Daniel 1988a, 1988b; Chute 1988). The Moss Rehabilitation Hospital provided clinical expertise, an appropriate patient population, and a suitable research and graduate training environment. Many rehabilitation centers typically do not have the space or funding for the required computer systems. The personnel from the various disciplines that need to be involved often have neither the time, nor the inclination, nor the technical expertise. Although rehabilitation facilities are developing cognitive retraining programs, frequently as independent departments, they typically concentrate on the application of the computer as a tutor in retraining and are limited by its marginal efficacy and increasingly doubtful funding. Instead such programs might wish to consider making the comparatively modest investment in applications programmers who can readily modify the new types of generic programs like HyperCard that can be used to created prosthetic tools for patients under the clinical guidance of the various rehabilitation specialists. The implication is that at discharge, each patient leaving the facility will have their own computer and the ProsthesisWare that has been specially customized for their unique needs.

New software distribution channels like Kinko's Academic CourseWare Exchange provide for the dissemination of software and HyperCard StackWare modules for a few dollars. Original equipment manufacturers like IBM and Apple have made major corporate commitments to the support and use of their products by the disabled. In our limited experience to date, the insurance industry in particular has been most supportive even though the initial outlay for equipment and software is relatively high. Their support takes a long-range view, where the versatility of the computer as a prosthetic tool is seen as contributing substantially to lowering life-time benefit costs. Household interfaces like MacLaboratory Controller, for example, permit a "higher" level of "home" placement where the computer effectively reduces the amount, and therefore the cost, of patient

Microcomputers: Tools *vs* Tutors in Rehabilitation

Theory of ADL		Computer Applications
Restorative	Tutor	Relearning via neuroplastic processes or alternate neural networks
Reconstructive	Tutor	Recovery of function through intense early training or by massed practice with general cognitive skills
Palliative	Companion	Social interactions and family activity, time filling, games
Prosthetic	Tool	ProsthesisWare, household and environment controllers, external memory and sequencing aids, speech and motor aids
Supportive	Tool	Caretaker respite, vocational and educational aids, environment interfaces

Efficacy		Delivery Problems
Marginal	Tutor	Lack of generalization
Undocumented	Companion	Arcade effect, juvenile
Face validity, untested	Tool	Need for customization

Figure 1. In rehabilitation, microcomputers have been used to supply drill and practice for general cognitive "exercise." Outcome efficacy has been marginal at best. A more recent approach uses the microcomputer as a tool providing individualized external prosthetic aids for the cognitively impaired. As a compensatory rehabilitation strategy such ProsthesisWare tools have face validity, but they have not been widely tested.

monitoring and supervision. The flexibility of the computer compared to single purpose dedicated prosthetic devices improves both the educational and vocational opportunities for some patients with a subsequent long-term cost savings. Ultimately such cost driven forces will determine the computer environment in rehabilitation facilities. Those that will be effective in the increasingly competitive rehabilitation market will be developing new structures and relationships for the microcomputer.

To be effective in the delivery of rehabilitation treatments and procedures employing microcomputer prostheses will require new neuropsychological assessment and treatment strategies. For example the need to tailor software to each individual's environment will de-emphasize traditional standardized assessments replacing them with more ecologically and valid multiple sequential monitoring of specific activities of everyday life (Hayden 1987).

The Role of Neuropsychological Assessment

Many neuropsychologists recognize that the emphasis on neuropsychological assessment in rehabilitation is moving away from diagnosis as that function is replaced by continuously improving neuroradiological techniques (e.g., Diller and Gordon 1981; Incagnoli 1986). Neuropsychological assessment, however, continues in the valued role of making behavioral and cognitive prognostication that is used in rehabilitation planning, discharge and vocational planning, and in evaluation of activities of daily living (Acker 1986). For the proper implementation of ProsthesisWare in the rehabilitation setting, new types and styles of neuropsychological assessments need to be added to provide software design and interactive feedback. Already conceptually similar timeseries assessments are increasingly used to monitor interventions, document changes over time, and predict the outcome of various pathological or recovery processes (e.g., Wilson 1987a; Gianutsos and Gianutsos 1987). Considerable effort has been expended to refine traditional assessment devices to better accommodate the changing emphasis from diagnosis to prognosis. Memory dysfunction is a common sequella of traumatic brain injury and other pathological processes and serves as an example of an area where modified and new neuropsychological procedures (e.g., Wilson, Cockburn, and Baddeley 1985) and assessments are being proposed and implemented (e.g., Erickson and Scott 1977; Russell 1987).

The Role of Neuropsychological Treatment

The neuropsychologist's role in treatment and neurorehabilitation has not been as well documented or clearly articulated as the role in assessment. There are a number of reasons for this including overlap with other disciplines on the neurorehabilitation team and the consequent lack of discipline-specific skills, as well as the lack of effective treatment strategies within a defined, consistent, and empirically founded theory of ADL. Typically there have been two main treatment avenues employed by the neuropsychologist in rehabilitation. Psychosocial interventions usually emphasize counseling for families and applications of therapies borrowed from clinical psychology and applied to patients who are neurologically impaired. This treatment avenue recognizes that preservation of the family structure and realistic self-evaluation by patients are important determinants of long-term outcomes. The second main avenue of rehabilitation treatment has been cognitive retraining (Wilson and Moffat 1983; Schacter and Glisky 1986; Parkin 1987).

Cognitive Retraining in Rehabilitation

The cognitive retraining strategies that have emerged are primarily focused on ameliorating problems with memory, attention, planning, organizing, executing, and performing activities of daily living. The most common strategy is to provide generalized training in the deficient cognitive capabilities with the hope that functional transfer will occur to the specific ADLs. Training has typically involved repetition and rehearsal and is often supported by software that functions as a tutor for drill and practice. The assumption, very loosely founded in basic neuroscience research, is that stimulation of general cognitive processes will promote relearning via neuroplastic events or invocation of alternate intact neural networks. Even though widely employed, there is little evidence that repetition, rehearsal, internal mneumonic strategies, or other forms of cognitive training will in fact generalize to functional ADL skills (cf Brooks and Baddeley 1976; Carr 1980; Chase and Ericson 1981; Cohen 1984; Moskovitch 1984; Prigatano, Fordyce, Zeiner, Rouche, Pepping, and Wood 1987; Wilson 1987b). The application of various memory and cognitive strategies that are employable in normal subjects (e.g., Craik and Lockhart 1976; Jacoby and Craik 1979; Intons-Peterson and Fournier 1987) are often prone to failure for functional ADL rehabilitation because they are not "ecologically based" in a way that is relevant to the patient's functional environment. Strategies that may be trained in normal subjects are difficult to acquire and may not be spontaneously used by patients if acquired, and they often do not recognize patient difficulties in self-generation of reasonable associations, rhymes, images, or acronyms. Even where the rehabilitation effort is clearly based on "training to task" for ecologically valid functions, the risk is that the practiced ADL skill such as personal hygiene, shopping, or whatever, will not transfer to the discharge environment (Mayer, Keating, and Rapp 1986).

The Microcomputer as a Tutor in Cognitive Retraining

The microcomputer is currently used extensively as a tutor to provide drill and practice in cognitive rehabilitation where general cognitive factors like memory, attention, orientation, and some ADL and school skills are "exercised" (Gianutsos 1980). However, the literature is equivocal in indicating that generalization of training in the cognitively impaired readily occurs (cf Bracy, Lynch, Sbordone, and Berrol 1985; Moehle and Shute 1986; Lynch 1988). Thus in rehabilitation strategies where restorative or reconstructive procedures are indicated, the microcomputer may contribute little to the outcome. Nonetheless, according to Bracy et al. (1985) some 73% of all rehabilitation programs used a microcomputer for that purpose and the number has no doubt grown since that study.

In fact the microcomputer used as a tutor for general cognitive skills may not have been an active, theoretically based application of the technology. Software that has been especially written for cognitive retraining is quite "primitive," highly variable in stability and consistancy of user interface, and inconsistent with neuropsychological principles (Lynch 1988). It may very well be the case, that inexpensive off-the-shelf educational products, simplistically coded routines, and games of a general nature have been widely used because the alternative of individually tailored software programming would be by far the more expensive and the slower to develop. The use of such generic software was justified by the hope that any generalization that did occur might be beneficial. Such programs could also be "administered" to patients by comparatively low level and therefore inexpensive staff. The history of comparative resistance of third party payment for computer based cognitive rehabilitation no doubt contributed to this low cost approach. The continued preference for arcane and difficult to operate 6502 and 8088 based systems, like Apple II's and IBM PC's, suggests that the availability of software was the major limiting factor in microcomputer use in rehabilitation. More advanced "patient friendly" systems like the current Macintosh or future IBM PS/2 (under Presentation Manager) have until recently been inaccessable except to the professional programmer; an expense that usually cannot be covered in the rehabilitation environment. When software for rehabilitation has been written, the need to spread the costs over a large number of patients had lead de facto to the embrace of a generalized tutoring strategy.

There exists an interesting parallel between the use of the microcomputer in cognitive retraining and its use in instructional computing. A survey of software catalogs will quickly reveal that most instructional software is tutorial in nature. Hewett (1986a) argues that the most useful role in instructional computing for college students is as a tool, rather than a tutor, and some classroom experience supports this contention (Chute 1987a). The computer becomes a tool when it has some useful application capability programmed into it. In this role the computer becomes an instrument which allows the individual to act upon and modify an important part of the environment. One purpose of this paper is to argue for a change in strategy in the use of computers in cognitive rehabilitation. There now exists a new class of software which can provide for easily individualized cognitive rehabilitation tools.

The Microcomputer as a Tool in Cognitive Retraining

Clearly the microcomputer can serve other roles in rehabilitation aside from cognitive retraining: for example as a prosthetic tool, as a supportive tool, and perhaps as a companion. The use of the microcomputer as a prosthetic tool, an external aid that does not presuppose any specific recovery of neurological function, has often been proposed (e.g., Jones and Adams 1979; Chute 1981, 1987b; Syndulko, Crooks, Wang, and Tourtelotte 1983), but not until recently actually implemented. We suspect that implementation required both the technological development of easy to operate, high resolution, graphically based, large capacity machines like the Macintosh, as well as readily customized authoring "shell" programs like HyperCard. For the microcomputer to function effectively as a prosthesis, software must be able to be affordably customized for the characteristics and needs of each patient. Until recently this precluded anything but a cottage industry type of approach. Typically the rehabilitation professional had neither the time nor the specialized and arcane programming talents needed to develop any software or even modify existing materials. Now, however, powerful, professional, and readily customized shell programs like HyperCard and interfaces like MacLaboratory for Psychology Controller (Chute, Gaeman, and Ziegler 1987) are available that require little if any computer programming to produce important prosthetic devices for the cognitively impaired. Prosthetic aids may be introduced in the rehabilitation facility, but they are typically intended for home, school or vocational placement and support. Effective software tools, however, require customization to the unique characteristics of each patient, and more expensive and more sophisticated microcomputer operating environments. Their comparative newness has not yet permitted complete evaluation as a utility for the rehabilitation patient. A secondary application of microcomputers as companions offers palliative and family social interactions whose effects could conceivably be to support important psychosocial rehabilitation.

Design of ProsthesisWare Tools for Rehabilitation

In our case, local circumstances created an environment and research infrastructure where the program customization limitations of using microcomputer tools in rehabilitation were in part overcome. Drexel University is repleat with suitable hardware (Smith et al. 1984; Chute 1986) and as part of its academic support program maintains a sophisticated Software Development Group (Perkey 1986; Westall, Perkey, and Chute 1986). The Drucker Brain Injury Center of Moss Rehabilitation Hospital has a long-standing history of clinical innovation and research support. In this context we would like to share our observations regarding hardware, software, and the design and implementation process of ProsthesisWare tools. We have selected for presentation the specific case of 'Cecelia R.', a traumatic brain injury patient, as an illustrative example.

Hardware Considerations

A good deal of effort has been expended by original equipment manufacturers and third party vendors to develop and supply hardware interfaces and special adaptive equipment to permit the disabled to become computer users (e.g., Schofield 1981; Bowe 1984). Typically these interfaces have been designed for the physically, but not the cognitively disabled person. It was generally but erroneously assumed that neurotrauma patients, for example, were equivalent to retarded individuals and little attention was paid to specialized cognitive needs. There are estimated to be over 50,000 people who sustain severe head injuries a year in the United States, some of whom could benefit from computer assisted ADL support. This group exceeds many others in size and special needs for hardware and software customization (Hutchins 1987).

In general we have favored Apple's Macintosh because the bit -mapped what-you-see-is-what-you-get screen image, the standard user interface, the ease of mouse based cursor movement, and the availability of more or less appropriate software have made it possible to use this computer more extensively as a prosthesis for head injured patients.

Software Considerations

The standard Macintosh user interface is one of the most important developments for computer use by people with cognitive impairments. Schacter and Glisky (1986) spent considerable time and effort teaching patients on an Apple II such general programming commands as List, Load, Save, Lock, Catalog, and Print. As is typical with head injured patients, special cuing and sequencing was necessary to perform some very basic functions. With the Macintosh many cues and functions are available or suitably handled by the standard user interface, permitting patients to use applications that are relevant to ADL and not just the operation of a computer for its own sake.

The recent release of HyperCard has provided one of the most important capabilities for the development of ProsthesisWare—functional and useful software products supporting the actual needs of cognitively impaired patients. HyperCard readily permits customization for each unique patient requirement. It permits a very rapid turn around in development, hours instead of months of a programmer's time. If permits prosthetic tools that range, for example, from speech synthesizers for expressive aphasics to interrelated "To Do" lists, calendars, and behavioral sequencers for amnesic patients. Although HyperCard requires more programming skill to set up than the average rehabilitation professional has available, its speed of development permits a multiple iterative process where the treatment team professionals can make recommendations and modification suggestions that reappear as functional software within a day or two (Hewett 1986b). Thus prosthetic applications like HyperCard or support applications like MacLaboratory Controller, which monitors household circuitry and security, form a new class of software functioning as individually designed rehabilitation tools. ProsthesisWare does not offer general training or presuppose that some rebuilding of the central nervous system is required for rehabilitation. Rather, ProsthesisWare specifically is customized to offer aid appropriate to the specific patient environment and context for any particular activity of daily living.

Standard User Interface Considerations

In our experience some features of the standard Macintosh user interface pose problems for some head injured patients. We mention some here because they illustrate characteristics of the problems faced by the cognitively impaired. For some head injured patients searching and finding strategies can be impaired. Thus items under a pull down menu are not only hidden, but may as well not be there. If, however, the command is visible, the patient is perfectly capable of appropriate action. HyperCard buttons or customized buttons in commercial software for hidden menu commands are necessary for some patients.

Some head injured patients have difficulty sequencing tasks and operations. If they acquire a sequence they are often much less flexible if any deviation or alternative is presented. Thus, such simple Macintosh features as closing a window using the close box, a Close command, or an implicit close due to some other action, can by their diversity confuse and disorient some head injured patients. Word usage inconsistencies are occasionally troublesome. "Empty Folder" for example contains no files whereas "Empty Trash" throws files away!

Head injured patients often extract some features from a situation, ignore others, and may have difficulty in fine discriminations. Thus, such closely allied functional tools as Zoom boxes and Grow boxes for sizing windows can lead to repetitive and perseverative errors with the standard user interface.

The file system (HFS) of the standard Macintosh interface is clearly superior for the head injured patient to other computer directories. However, the head injured patient can still have difficulties. For example, one patient we observed could keep track of information stored on a labeled floppy disk beside the computer that could be inserted in the machine, but could not find the same material if it were contained in a folder on the hard disk. In general, patients who supply their own naming and filing systems do better. (e.g., Wilson and Moffat 1983). Many keep track of information by positional information on the display and thus such functions as "Clean Up" can be disabilitating. For some patients file icons serve as very useful cues. For others, however, the name is the most important feature. Neuropsychologists might suspect this would relate to lateralization of neurological impairment, however, we have no consistent data in this regard for patients with traumatic brain injuries. Filing, sorting, storing, and naming can be major limitations for successful use of noncustomized and commercial software. These classes of software are important because they offer the head injured patient greater vocational and educational prospects. Often the family or another support system has to be trained to help with the day-to-day management of filing operations. Some desk accessories like "Find File" are useful where the problem is only physical location, but most problems for the head injured occur from lack of effective naming strategies. "Find File" is not much use when nearly all files have similar, if not identical, names of limited descriptive value.

Although the standard user interface more closely approximates a patient friendly system there is a clear need, depending on the patient, for specialized training to be provided by the rehabilitation team. As is often the case in the field, family and other support systems are needed in order to maximize the utility of the computer.

"Cecelia R.": A Case Study

Cecelia R. is a 37-year-old white female injured in August of 1986 in a motor vehicle accident. She was thrown from the car and found unconscious on the side of the road. She suffered a severe closed head injury with cerebral contusions and hemorrhage, multiple rib fractures of the left chest, and trauma to the bladder. A subsequent infection required an amputation of the left leg below the knee. A persistent low grade fever, perhaps a central hyperpyrexia, was treated with Clonidine and by addressing secondary infections.

Cecelia R. remains severely limited physically. She is dependent for all ADL skills. Her arms are splinted due to increased tone and their only movement is reflexive with a head thrust eliciting an asymmetric tonic neck reflex. However, Cecelia can control movement in her right thumb with both abduction and opposition providing a range of movement of about 5 cm., but she is unable to flex the thumb. She has good head control at times and is able to track information visually.

Cecelia has an expressive aphasia and her communication has been limited to yes/no nods of her head. She responds with 80–90% accuracy to reading comprehension passages. No formal neuropsychological testing has been performed. However, reports from occupational and physical therapy and speech show memory for tasks, but with some possible reasoning difficulties. As a locked-in patient with apparently reasonable receptive language capabilities, Cecelia became a candidate for a ProsthesisWare development project. Somewhat inadvertent neuropsychological observations occurred during the design and testing of various iterations of the software. It became evident that Cecelia's memory might be more limited than was hoped. For example, the computer enabled her to ask questions like "What has happened to me"? Unfortunately she is still unable to remember the answers she is given. Her memory difficulties exposed by the software development process, combined with her inability to successfully gain control of the cursor, lead to successively more simplified software designs.

Using HyperCard for the Macintosh, the succession of stacks or programs were created which became known as SpeakEasy, SpeakEasier, and SpeakEasiest (Chute and Hoag 1988). They represent successive full-featured programs that were implemented in an attempt to provide the most appropriate speech prosthesis for Cecelia. With each of them words and phrases can be assembled and "spoken" through the MacinTalk™ speech synthesizer system software widely distributed by Apple. Physical limitations obviated the effective use of the mouse so a modified trackball and microswitch were set up in a configuration under Cecelia's right thumb. With this arrangement she was able to move the cursor mostly along the "x-axis" and to click selecting letters, phrases, or functions which could print or speak created text. Ultimately, Cecelia was not able to learn effective control of the cursor. Having reached the maximum excursion of her thumb, she seemed incapable of acquiring the motor skill of repositioning it for continued movement. Instead, she would become "stuck" in a nonproductive perseverative action at the extreme of her range of movement. This is analogous to the awkwardness experienced by first-time "mouse" users, although, unlike them, Cecelia was not able to make any progress over three weeks. This failure could not be attributed to peripheral motor or sensory deficits of her thumb. The final design for Cecelia occurred by an evolutionary process and resulted in SpeakEasiest, which required only clicks to control a semiautomated cursor.

The Design Process

As suggested by Hewett (1986b), the design of interactive software should be thought of as an iterative process involving evaluation of results as an integral part of each design and redesign cycle. Viewed from this perspective, the design process is as instructive for its failings as well as for its successes. Each design cycle in its way constitutes a new type of neuropsychological evaluation for which there are as yet no norms or standardized procedures.

From Cecelia's case, and others, we have attempted to articulate some general principles which may serve as a guide to others as HyperCard and other easily authored software packages become readily available to rehabilitation professionals. Initially, the first HyperCard stack for Cecelia was created independently by a graduate student, Paul Stafiniak, who had become interested in Cecelia's case. It consisted of the alphabet written across the screen forwards on one row and backwards on a row below. Cecelia needed to click once with the mouse button to move the cursor across the line to select letters. Once a letter was selected she would look to an assistant, who would write it down to begin to form a word or sentence. Although the design was a simple prototype, the capability inherent in HyperCard made it functional. Cecelia was able to communicate using this tool. Her first communication, more than a year posttrauma, was "Fuck You." The lesson for design at this stage was the importance of the extremely quick ability afforded by HyperCard to create a functional prototype. Although Cecelia's first words were cryptic, they had the effect of mobilizing the rehabilitation team and justified the expenditure of hardware and software resources in her behalf.

Having demonstrated that Cecelia was able to generate language, an analysis of the limitations of the original stack was conducted to begin design on a second. To reduce confusion, letters were arranged as buttons in the QWERTY keyboard fashion familiar to Cecelia and consistent with a portable device she was also learning to use. To reduce fatigue, words that were constructed could be put in scrolling lists and accessed with a single click. Figure 2 shows the Keyboard Worksheet from this early version called SpeakEasy.

To provide for quick communication, large function buttons with appropriate icons were created on separate cards. For example, with one click Cecelia could say "Please turn on the TV", or "I am cold." With an eye to getting the most from the computer's flexibility at some future date, standard Macintosh user interface was adhered to, and editing functions like Cut, Copy, and Paste buttons provided. Since organization is often a problem for the traumatically brain injured patient, buttons were provided connecting the speech prosthesis portion to speaking To Do lists and an Organizer. These were

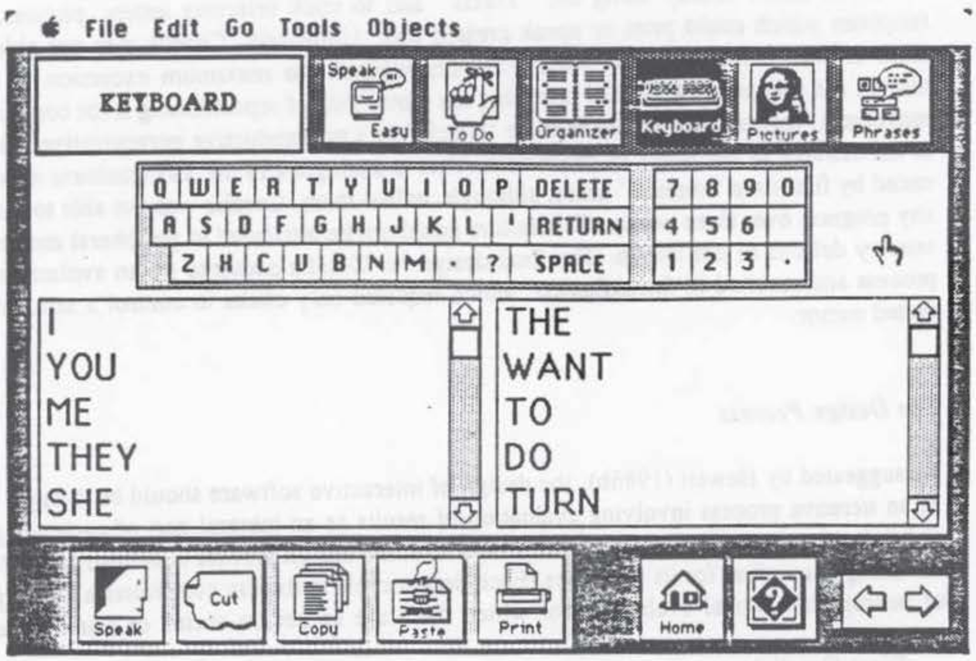

Figure 2. SpeakEasy© runs using HyperCard™ on an Apple Macintosh™ computer with at least 1 meg RAM and a hard disk. The Worksheet Buttons across the top row provide access to different functions like a To Do list, Organizer, or as illustrated, a mouse operated "click-on" Keyboard. The Tool Buttons on the lower left permit selected text to be spoken or printed. The standard user interface is maintained and supports editing functions like Cut, Copy, and Paste. On the lower right of the screen the Home Button accesses other HyperCard stacks, the Help(?) Button provides on screen information and advice for all buttons, and the Turn Page arrow brings up controls for the MacinTalk voice synthesizer, user preferences and user levels.

designed to accept text that assistants or the health care team might also enter. On screen Help buttons were provided for all functions, not only for the benefit of Cecelia, but to make it easy for others around her to use the program. Figure 3 shows the Pictures Worksheet, another feature of the early version of SpeakEasy.

For Cecelia, SpeakEasy was a failure. The reasons why are important considerations in ProsthesisWare design. Most importantly there must be an appropriate software/patient fit. SpeakEasy may be useful for many patients with expressive aphasias, but it did not fit well for Cecelia with her limited memory and ineffective cursor control. SpeakEasy was visually and functionally too complex for her, although it served the useful purpose of proving that to be the case. Even though experienced in the team approach to rehabilitation, we got caught in the trap of developing elegant software with many features, while neglecting to consult with team members. Perhaps most important to Cecelia was her frustration and fear that she would fail at her chance to communicate. The window that had so suddenly been opened might just as easily be shuttered.

Whenever she would begin to work with the computer it was explained to Cecelia that the team was trying to develop a communication system for her so that people would be able to know what she was thinking and feeling. When we asked Cecelia if she thought that the staff should know what she was thinking, she replied "Yes." The patients must want to actively participate in their rehabilitation process to maximize results. This had been an issue for quite some time with therapists on the team, and some felt that Cecelia

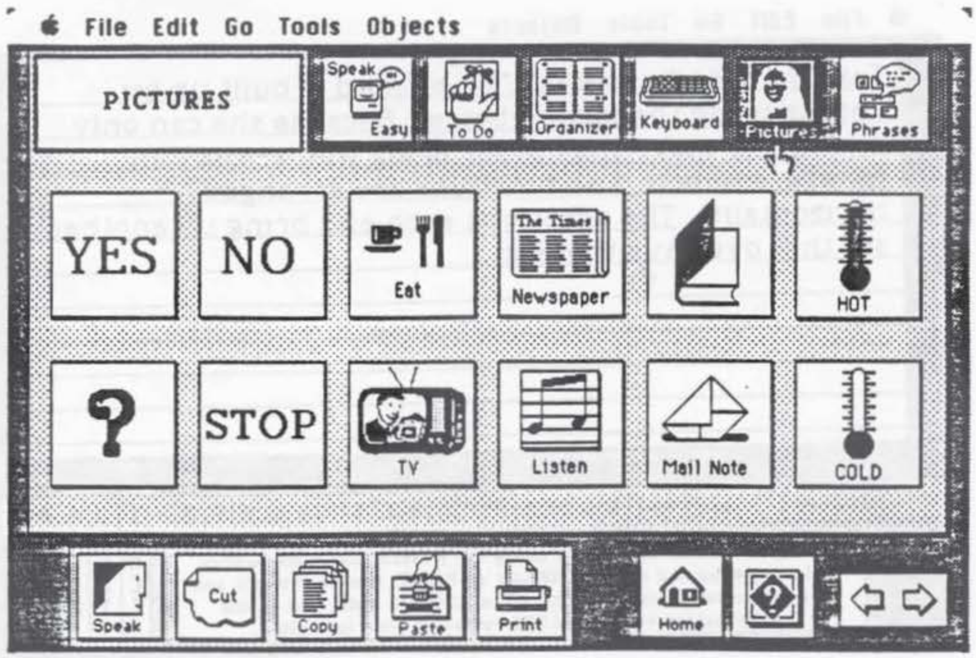

Figure 3. The Pictures Worksheet contains user defined buttons and their icons which "speak" whole sentences or phrases when clicked. The patient or the rehabilitation specialist can easily change what is spoken by typing in English, in the appropriate line of script. If additional buttons or icons are required, new pages can be added. The Pictures Worksheet makes many daily communications less onerous than the Ouija Board like assembly of individual letters, words, and phrases.

was not willing to participate in her therapy. It was felt by others, however, that Cecelia was deeply frustrated and perhaps if the right "tool" were developed she would respond more willingly. The issue made it difficult to determine if software design was at fault, or if the patient was simply not being compliant. Her first words would make one wonder.

In some ways our past experience with software development was an impediment to correctly staging successive levels of functionality until Cecelia reached asymptotic performance. In the past software took so long to produce that one needed to anticipate where the patient would be in the comparatively distant future. We overlooked the power of HyperCard to provide for quick development when we skipped over the stage that was most appropriate for Cecelia at that moment. Three days later we produced SpeakEasier, a straight forward design that allowed Cecelia to construct and speak messages. We continued with refinement of the track ball and switch input hoping that she might gain sufficient control over the cursor that a broad range of ProsthesisWare might be constructed for her use. Figure 4 shows the primary screen of SpeakEasier.

Unfortunately Cecelia was unable to control the cursor sufficiently well for her to be able to communicate using SpeakEasier without a great deal of frustration and constant assistance. For the next design cycle we felt obliged to abandon our attempts to achieve cursor control. Thus the final design was SpeakEasiest, which employed a semiautomated floating cursor. Figure 5 illustrates its main screen.

Discharge Planning and ProsthesisWare

Unlike most software used for cognitive retraining in the rehabilitation facility, ProsthesisWare is intended to support the activities of daily living in the eventual discharge

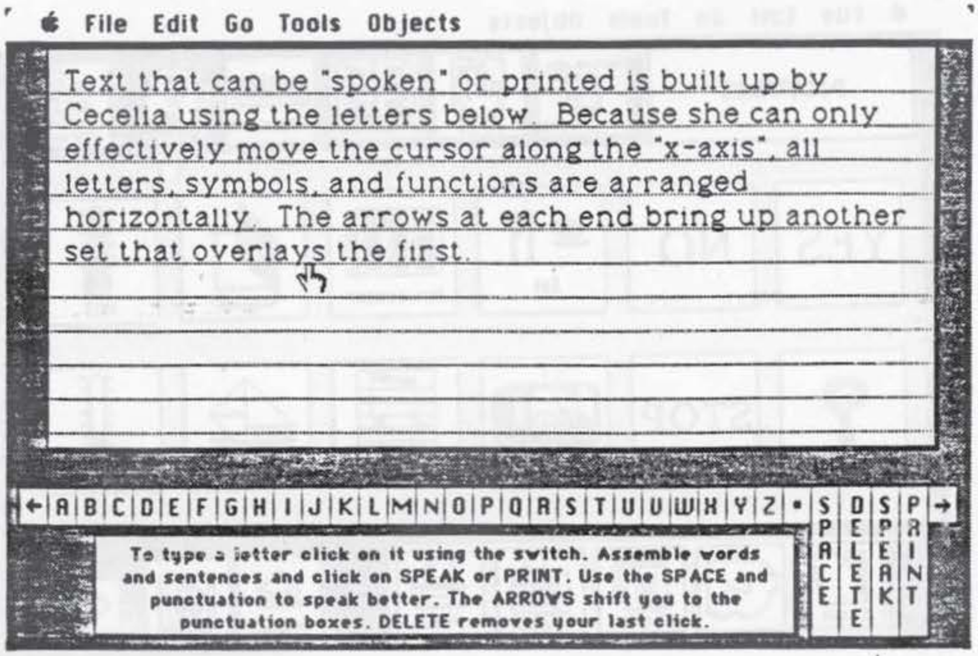

Figure 4. A simplified design called SpeakEasier incorporates features consistent with Cecelia's capabilities. Effective ProsthesisWare design should incorporate the experience of the rehabilitation treatment team. At this stage in the development process we were hoping that Cecelia could learn to handle cursor movements well. Unfortunately this did not happen so another design iteration with a semiautomated floating cursor was produced.

environment. In Cecelia's case her physical dependency will result in her placement in a nursing home. Some of the concerns raised by the treatment team reflect issues that need to be addressed in software design, hardware set up, and configuration. We also suspect that some expressed concerns reflect a degree of "technophobia" and the cautions surrounding new, and at times, discipline threatening techniques. To justify support through healthcare funding channels, the software that is designed must actually deliver, and not just promise, utility and functionality for the rehabilitation patient.

The Macintosh itself is viewed as cumbersome and is seen as not sufficiently portable for movement around the nursing home environment. If she ever acquires cursor control skill, Cecelia will require that her hand be carefully positioned and maintained over the track ball. Although an adaptive living engineer could probably arrange a gimbal attachment to her wheel chair, it is unclear whether custodial staff would accommodate the added complexity. The putative portable Macintosh could only solve part of this problem. To speak with her children is important to Cecelia, however the hardware and software does not at this time permit a direct telephone coupling for MacinTalk speech/voice communication. Cecelia would not have the resources to fund such development. At best, an assistant will have to establish a phone link by juxtaposing a speaker telephone. Training of staff and equipment maintainance to handle various sorts of system failures are not regularly supported or provided for in the nursing home environment. The rehabilitation hospitals and facilities themselves are also not prepared for even basic user support. Perhaps the capability of ProsthesisWare products to improve daily living skills will lead to investment in a support infrastructure to provide programming and user services. The potential for "turn-key" operating systems characteristic of the Macintosh,

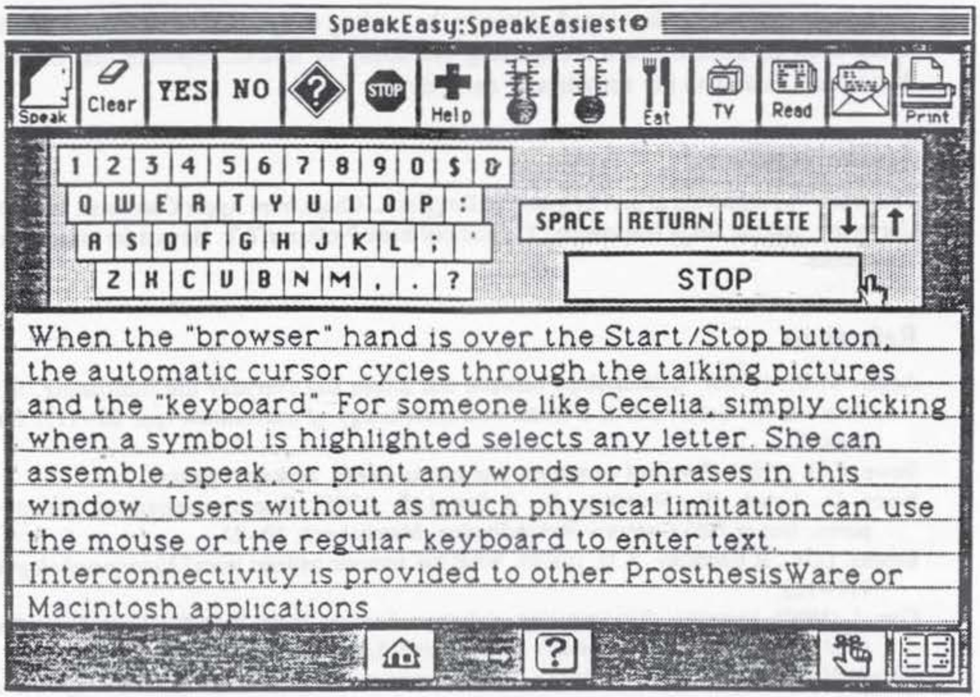

Figure 5. The final software version, SpeakEasiest, is illustrated. Cecelia has a level of functional language appropriate for her. Family, assistants, and other users have available normal editing functions and ready access to other ProsthesisWare and related applications.

and the ease of HyperCard programming, have greatly reduced the costs that would be involved in supplying such a computer support infrastructure.

When Cecelia communicates either with her portable board or through her software she asks "What's wrong with my memory? Why am I here? Who pays? Why do they torture me?" We hope in following her case that she will continue to improve and that the nursing home will be inclined to support her ability to communicate with the "outside" world.

Summary

Using the microcomputer as a prosthetic tool in rehabilitation has a number of advantages over using it as a tutor for cognitive retraining. As a tool, the microcomputer program directly addresses ecologically relevant issues in activities of daily living. Customized fairly easily, using shell programs like HyperCard or MacLaboratory Controller, it can be fitted to each patient's needs. Unlike tutors used for cognitive retraining, rehabilitation tools provide prosthetic support that does not presuppose any required reorganization or restructuring of damaged neural tissue. With the Macintosh computer, ProsthesisWare tools employ the standard user interface and relieve the memory overburden by providing external function and sequencing cues. The case of Cecelia R. illustrates how new hardware and software capabilities permit the rapid, iterative design and redesign of cognitive prostheses. However, the rehabilitation infrastructure supporting microcomputer implementation needs to be developed. Already the leading centers in rehabilitation are developing such an infrastructure recognizing the utility of microcomputers that offer prosthetic tools as aids to the activities of daily living.

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