Assistive Technology for Postsecondary Students with Learning Disabilities: An Overview

Marshall H. Raskind and Eleanor L. Higgins

Abstract

The number of postsecondary students with learning disabilities has increased dramatically over the last several years. This increase, coupled with federal legislation mandating “academic adjustments” for students with disabilities, has prompted the development of postsecondary learning disability support service programs. One support service that has begun to attract considerable attention is assistive technology. The purpose of this article is to provide an overview of assistive technology as it relates to postsecondary students with learning disabilities by (a) briefly tracing the development of assistive technology service for postsecondary students with learning disabilities; (b) identifying basic models of assistive technology service delivery and specific services; (c) providing a description of specific assistive technologies; (d) reviewing research on the effectiveness of assistive technology with postsecondary students with learning disabilities, with a focus on the authors’ 3-year federally funded study; and (e) concluding with a summary and recommendations.

Since 1985 the number of students with learning disabilities (LD) entering postsecondary programs has grown faster than any other disability classification (American Council on Education, 1992). Although statistics are not readily available as to the precise number of postsecondary students with LD, data from the American Council on Education and the National Center for Education Statistics (1989) suggest that the figures range from 160,000 to 300,000. In fact, according to Jarrold (1987), executive director of the Association of Higher Education and Disability (AHEAD), students with LD are the “single largest contingent of students with disabilities being served on American campuses” (p. 46).

This increase in the population of students with LD, coupled with federal legislation (Section 504 of the Rehabilitation Act of 1973, Subpart E) mandating “academic adjustments” for students with disabilities, has prompted postsecondary institutions to develop LD support service programs aimed at promoting academic retention and success (Beirne-Smith & Deck, 1989; Vogel, 1987; Vogel & Adelman, 1993). Although the specific services offered by individual programs vary (Shaw, McGuire, & Brinkerhoff, 1994; Vogel, 1993), programs often provide readers, note takers, tutors, counselors, academic advisors, advocates, compensatory strategy instruction, diagnostic assessment, and test-taking modifications. In addition to the above services, postsecondary LD support programs are offering increasing levels of assistive technology (sometimes referred to as “auxiliary aids” or “adaptive technology”; Adelman & Vogel, 1993; Bryant, Rivera, & Warde, 1993; Mellard, 1994; Raskind & Scott, 1993; Rothstein, 1993; Shaw et al., 1994).

According to the Technology-Related Assistance for Individuals with Disabilities Act of 1988 (P.L. 100-407), an assistive technology device refers to “any item, piece of equipment, or product system, whether acquired commercially off-the-shelf, modified, or customized, that is used to increase, maintain or improve the functional capabilities of individuals with disabilities.” For the purposes of this article, assistive technology is further delineated as any technology that enables an individual with LD to compensate for specific deficits. In some instances the technology may assist or augment task performance in a given area of disability, while in others it is used to circumvent or “bypass” (not remediate) specific deficits entirely.

A review of the approximately 1,000 listings in Peterson’s Colleges with Programs for Students with Learning Disabilities (Mangrum & Strichart, 1992) indicates that virtually all LD support service programs provide some form of assistive technology (listed under “auxiliary aids”) to their students. These assistive technologies are most likely to include basic devices, such as tape recorders, word processors, spell checkers, and calculators. To a much lesser extent, many programs also offer speech synthesizers, optical character recognition (OCR) systems,
listening aids, and speech recognition systems.

The purpose of this article was to provide an overview of assistive technology as it relates to postsecondary students with LD. Specifically, we will (a) briefly trace the development of assistive technology service for postsecondary students with LD; (b) identify basic models of assistive technology service delivery and specific services; (c) provide a description of specific assistive technologies; (d) review research on the effectiveness of assistive technology with postsecondary students with LD, with a focus on the authors' 3-year federally funded study; and (e) conclude with a summary and recommendations.

The Development of Assistive Technology Service Delivery

It is difficult to determine the precise factors that led to assistive technology use with postsecondary students with LD. The entry of assistive technology into postsecondary LD programs was undoubtedly the result of multiple forces and influences both within and outside of postsecondary institutions, and reflects the growing interest in and use of technology in society as a whole. Such forces likely include the growth of technology (e.g., academic computing, electronic information systems) on postsecondary campuses, the tremendous influx of persons with LD into postsecondary settings, federal legislation that mandates "academic adjustments" (including the availability of auxiliary aids), as well as the increased financial and personnel demands of providing support services to the ever-growing population of individuals with LD (Vogel, 1987). The provision of assistive technology (e.g., tape recorders, OCR) to students with other disabilities may also have acted as a catalyst. Additional factors include the growing awareness on the part of technology developers/manufacturers (e.g., Xerox, Humanware) of the need for LD products, and the vast LD market; the passage of the Americans with Disabilities Act of 1990; Section 508 of the Rehabilitation Act of 1973 (the Act was amended in 1986); the Individuals with Disabilities Education Act of 1990 (which now includes specific mention of assistive technology); and the Technology-Related Assistance for Individuals with Disabilities Act of 1988.

There are a number of other traceable forces that have made a major contribution to promoting the use of assistive technology, although it is impossible to determine the exact manner in which they influenced postsecondary LD programs or their degree of impact. These forces include the establishment of the High-Tech Center for the Disabled of the California Community Colleges Chancellor's Office in 1986, which led to a network of more than 100 High-Tech Centers for the Disabled. These centers were designed to provide students with disabilities, including LD, "training in, and access to, supportive technologies that would allow them to compete effectively in both academic and workplace environments" (Brown, Norris, & Rivers, 1989, p. 389) and also establish research, evaluation, and training facilities for directors of disabled student service programs at all of the 107 California community colleges. Project EASI (Equal Access to Software and Information), founded in 1988 as a special interest group of EDUCOM (a consortium of over 600 colleges and universities and approximately 100 corporate associates), has also played a prominent role in promoting the use of assistive technology for postsecondary students with LD. This group has acted as a leading resource for the higher education community on developing computer support service for persons with disabilities, via seminars, online workshops, and numerous publications on "adaptive computing technology," including technology for persons with LD.

The California State University, Northridge (CSUN), Center on Disability also had an impact on the area of assistive technology and postsecondary students with LD when it initiated (in 1985) one of the first conferences on technology and disability and created a specific topical strand on assistive technology and postsecondary students with disabilities. This provided a forum for some of the first presentations in the area. The CSUN program also established a comprehensive LD support service program and computer access lab in 1985, which provided a vast array of assistive technology to students from a number of disability categories, and the opportunity to intensively explore the potential benefits of numerous assistive technologies for postsecondary students with LD. These initial informal investigations set the stage for a series of formal research studies on the effectiveness of several assistive technologies with postsecondary students with LD, which will be discussed later in this article.

In addition to the aforementioned organizations and programs, Murphy (1991), in a report from the National Council on Disability, identified 17 exemplary technology-support programs for postsecondary students with disabilities, 9 of which include services for students with LD. These programs have acted as models in the area of assistive technology and postsecondary students with LD and include Disabled Student Services, University of Wyoming; the Assistive Technology Center, University of Minnesota; the Disabled Computing Program, University of California, Los Angeles; the Office of Services for Students with Disabilities, University of Nebraska; the Adaptive Computing Technology Center, University of Missouri; the Adaptive Technology Laboratory, Southern Connecticut State University; and the Center for the Vocationally Challenged, Grossmont Community College in El Cajon, California. The two remaining programs include those already discussed, the California Community College High-Tech Center, and the CSUN program.
Delivery of Assistive Technology to Postsecondary Students with LD

Assistive technology service delivery models and services vary considerably among institutions. Although no nationally representative random sample of assistive technology service delivery for students with LD currently exists, basic models and practices can be discerned from a review of the limited literature (Brown, 1987; Burgstahler, 1992; Cutler, 1990; EASI, 1991; Horn & Shell, 1990; Murphy 1991; Raskind & Scott, 1993). First of all, the institutional office or department charged with managing assistive technology services varies from campus to campus. In most instances the provision of assistive technology is managed by either disabled student service offices, academic/departmental computing services, or the institution's central computing department. Murphy indicated that out of the nine exemplary technology-support programs reporting LD services, four were coordinated by the office of disabled student services, four by the central computing department, and one program was “self-managed.” Similarly, Burgstahler, in a survey of technology services for students with disabilities at 1,200 postsecondary institutions, found that the departments most likely to manage computing services were, in descending order, disabled student service offices, central computing services, and departmental computing services.

The location of the assistive technology also differs from one institution to the next, with some programs distributing assistive technology throughout the campus (distributive model) at existing computer sites, and others providing assistive technology at a central location. Proponents of the distributive approach assert that it is more in line with federal regulations mandating integration of students with disabilities, and that it helps ensure greater access to the full range of campus-computing resources, while advocates of the centralized model argue that housing assistive technology services in a central location results in greater levels of student satisfaction and success, as well as more efficient delivery of services (Burgstahler, 1992). According to Burgstahler, the majority of postsecondary disabled student service providers endorse the distributive model.

In addition to the management and location of assistive technology, programs also vary considerably in regard to the specific services provided. These variations can involve (a) a range of assistive technologies available (e.g., OCR, spell checkers, word prediction, abbreviation expansion, speech recognition, outlining, speech synthesis); (b) the specific brands or models of assistive technology provided (e.g., DragonDictate™ vs. Kurzweil Voice™ speech recognition); (c) the extent and model of training or support provided; (d) the background/expertise of the personnel providing training or support; (e) the degree of technical support offered to students; (f) the presence or absence of “user groups”; (g) whether or not an equipment loan program exists; and (h) provisions for funding. Again, there are no published data to help determine the exact assistive technology services provided to postsecondary students with LD across the nation.

Overview of Assistive Technologies

This section will present an overview of assistive technologies currently available for assisting adults with LD (space limitations will not permit a discussion of all technologies; see Note 1). The technologies discussed in this section have been suggested for use with postsecondary LD students by a number of authors (e.g., Brown, 1987; Bryant et al., 1993; Raskind & Scott, 1993; Shaw et al., 1994). Recommendations are based primarily on case studies and clinical observations and are not necessarily supported by formal research (research on assistive technologies will be discussed in the next section). The authors of this article have utilized these technologies with approximately 400 students over a 8-year period in the Learning Disability Program and Computer Access Lab at CSUN (part of the Office of Disabled Student Services).

Technologies will be discussed relative to the difficulties experienced by postsecondary students with LD and grouped according to the area of disability the technology is intended to circumvent. Several of the technologies have more than one application and thus will be listed under more than one heading. It is important to stress that not all the technologies discussed are appropriate for all students with LD, and that a technology that might be extremely valuable to one person might be ineffectual, or even detrimental, for another. Therefore, it is imperative that technologies be chosen relative to the particular individual’s strengths, weaknesses, interests, and experiences; the function to be performed; and the context of interaction.

Written Language

Word Processing. The written language difficulties of adults with LD have been well documented (e.g., Gregg & Hoy, 1989; Hughes & Smith, 1990; Johnson, 1987; Vogel, 1985). In fact, Blalock (1981) asserted that between 80% and 90% of adults with LD exhibit written language disorders. Several researchers (e.g., Collins, 1990; Primus, 1990) have found word processors valuable in helping persons with LD compensate for written language difficulties. Unlike the conventional methods of writing with pencil and paper or typewriter, word processors enable users with LD to write without having to be overly concerned with making errors, as text can be easily corrected on-screen prior to printing. When not preoccupied with the mechanical aspects of writing, persons with LD have a greater opportunity to focus on making meaning. This is
of particular importance for those individuals who have developed a fear of translating their thoughts into written language as the result of a history of writing problems and the criticism that often follows. Knowing that they can simply generate language and correct errors later may reduce their anxiety, liberate their writing abilities, and ultimately facilitate written expression at a level commensurate with their intelligence. Furthermore, word processing may lead to neater and cleaner documents, which may in turn help foster in students a sense of pride in their written work and enhance their image of themselves as writers.

Although levels of complexity of word processing programs vary considerably, most postsecondary students with LD should be able to learn basic operational procedures within 2 to 3 hours. The cost of word processing software ranges from approximately $100 to $300. A computer to run the software and that is of a quality sufficient to meet the needs of a postsecondary student with LD can be purchased for around $1,000 to $1,500.

**Spell Checking.** Many adults with LD have written language disorders that include difficulty with spelling (Johnson, 1987; Vogel & Moran, 1982). The use of spell checkers (generally included in word processing programs) can help compensate for such problems, as they permit the user to check for misspelled words within a document before a final copy is made. Spell checkers match the words in a document against words in the spell checker's dictionary, and if a match is not found, the user is alerted by a visual or auditory cue and is presented with a list of words from which to choose the correctly spelled word. The user selects the correct word and the computer automatically corrects the misspelled word in the text. Some spell checkers alert the user to spelling errors while typing (which may be disruptive to some students), whereas others check for mistakes after the document has been completed.

Selecting the correct word from a list of options can be a difficult task for many LD students. Cross-checking the words for synonyms in the word processor's thesaurus or dictionary (if available) can assist in the selection process. The use of a speech synthesizer/screen reader (see the following section) may also help the user identify the correct word.

In addition to spell checkers that are part of word processing programs, there are also battery-operated standalone spell checkers that are available in desktop and pocket sizes. Basic units will simply verify and correct spelling on a liquid crystal display (LCD), whereas more sophisticated devices also provide dictionaries and thesauruses. Some of these units are now equipped with speech synthesizers, which enable the user to hear, as well as see, the word in question, definitions, synonyms, and help messages. Prices range from approximately $30 for basic checkers to $500 for more sophisticated units with speech synthesizers. These products are relatively simple to use and generally require no more than 15 minutes to 1 hour to learn to operate.

**Proofreading Programs.** Adults with LD who experience written language problems may also benefit from the use of proofreading programs. These software programs (now included in many word processors) scan word processing documents and alert users to probable errors in punctuation, grammar, word usage, structure, spelling, style, or capitalization. Most of these programs can be used to either mark probable errors or mark the error and attach a commentary (e.g., “Be sure you are using ‘is’ with a singular subject’). Many programs include online tutorials that allow the user to study the language rules checked by the program.

It is important to stress that proofreading programs are not completely accurate and will not pick up all grammatical errors or objectionable phrases in a document. They may also make incorrect suggestions, sometimes prompting the user to correct elements of writing that are not really incorrect. In addition, some individuals with LD may find these programs demeaning, with the technology playing the role of an intolerant “electronic teacher,” criticizing them and possibly intensifying feelings of incompetence and low self-esteem. Proofreading programs can usually be purchased for under $100 and require about 1 hour of training before they can be used reasonably well.

**Outlining/Brainstorming.** Although some individuals with LD may have great ideas in their heads, getting them down on paper may be another story. Writing that first word or sentence can be an insurmountable task; and even if the person can get started, he or she may have difficulty determining how to proceed. Many persons with LD have difficulty organizing a paper with regard to topic, categories, and sequence (Johnson, 1987). Outlining programs (now included in most standard word processing programs) can help with such difficulties because they enable the user to “dump” information in an unstructured manner—information that can subsequently be placed in appropriate categories and order.

Although each program has its own features, generally, the user types in any idea or thought on a specified topic, without regard to overall organization. By using a few simple keystrokes (or, with a mouse, pointing and clicking), the outlining program will automatically create the Roman numerals for major headings, and letters and numbers for subordinate headings. The user need not be concerned with order, levels of importance, or categories, as text can be easily moved at a later time. Once basic ideas have been written down, those ideas that are related, or that seem to “go together,” provide the basis for major headings or categories. Ideas that fall under any major heading can be easily reduced to any level of sub-
ordinate heading. Even if the user determines at a later time that an idea does not belong under a certain heading, this does not pose a problem, because any piece of text can easily be moved within the outline, as many times as necessary. The program automatically reorganizes the Roman numerals, letters, and numbers designated for specific headings. Outlining programs also enable users to limit what is viewed on the computer screen to only the major headings, to facilitate an overview of the document, as well as to select single subordinate headings and view all information under it for a detailed analysis. This may be a useful option for persons who become so focused on details that they cannot see the big picture, or, inversely, for those whose writing is excessively “skeletal” and lacking in detail.

Programs (e.g., Inspiration®) also exist that have graphic capabilities that can facilitate brainstorming by enabling the users to create a diagram of their ideas (semantic webs, “mind maps,” cluster diagrams) prior to formulating an outline. The user types in a main idea that is displayed on the screen. Related ideas are then input and appear in specified geometric shapes (e.g., circles, ovals, rectangles) surrounding the central idea. Ideas may be linked with the main idea (and each other) by lines. Ideas can easily be moved, rearranged, and categorized. Detailed notes can also be attached to specific ideas and hidden from view. Ultimately, the graphic representation can automatically be converted to an outline. This nonlinear, “free-form” graphic approach may be even more helpful than simple text-based outlining to some students.

Outlining programs and graphic organizers usually require about 1 to 3 hours of practice before they can be used with any degree of proficiency. “Add-on” outlines are available for between approximately $100 and $400. Graphic organizers cost about $90.

**Abbreviation Expanders.** Abbreviation expansion is used in conjunction with word processing and allows users to create their own abbreviations for frequently used words, phrases, or standard pieces of text, thus saving keystrokes and, ultimately, the amount of time it takes to prepare written documents. This is an important consideration in light of the fact that some students with LD take longer than their nondisabled peers to complete tasks (Blalock & Johnson, 1987). For example, a student with LD in a history class who has to frequently type out “industrial revolution” in completing written assignments might create the abbreviation “ir.” To expand an abbreviation, the user simply types in the abbreviation and presses the space bar on the keyboard (or, depending on the particular program, points and clicks), and the abbreviation is expanded into its original form. Abbreviations are easily recorded by executing a few simple commands and can be saved from one writing session to another.

Abbreviation expansion is an integral part of some word processing programs and is also available as “memory resident add-on” programs (operating simultaneously with the word processing program). Add-on programs run about $100. Less than 1 hour of training is generally needed to learn to use abbreviation expansion.

**Speech Recognition.** Speech recognition systems appropriate for use by postsecondary students with LD operate in conjunction with personal computers (and certain laptops) and consist of speech recognition software, a sound-board, headphones, and a microphone. Speech recognition systems enable the user to operate the computer by speaking to it. This can be particularly helpful to individuals with LD whose oral language exceeds their written language abilities (King & Rental, 1981; Myklebust, 1973). When used in conjunction with word processors, sophisticated systems (e.g., DragonDictate™, Kurzweil Voice™, IBM® Voice Type™) enable the user to dictate to the computer at 40 to 70 words per minute (depending on the speed of the computer), converting oral language to written text. These systems automatically “learn” the phonetic characteristics of a person’s voice while he or she dictates to the system. The more the system is used, the better able it is to understand what the user is saying.

To operate the system, the user dictates through a microphone. At present, most systems require a calculated pause of approximately 1/10th of a second. (Recently released “continuous speech” systems do not require a pause.) The word the system “thinks” the person has spoken is placed on the screen. If the word is incorrect, the user can choose the correct word from a list of similar-sounding words that appear on the screen. It should be noted that all keyboard editing and control commands (e.g., “delete word”) can be done with the voice alone.

It takes approximately 2 to 3 hours to train a student with LD to work independently with the system. Training has two components: instruction in the basic operational procedures, and training the system to recognize the user’s voice. The cost of speech recognition systems ranges from approximately $100 (for single application versions) to $1,000 (not including the sound-card or computer).

**Speech Synthesis/Screen Reading.** Several authors have suggested that speech synthesis be used as an assistive technology for postsecondary students with LD (e.g., Brown, 1987; Norris & Graef, 1990). Speech synthesis refers to a synthetic or computerized voice-output system usually consisting of an internal board or external hardware device. In conjunction with “screen reading” software, a speech synthesizer will read back text displayed on a computer screen so that the user can hear as well as see what is displayed. Text can be read back a letter, word, line, sentence, paragraph, or screen at a time. Screen-reading programs (e.g., SoundProof®) that are specifically
designed for individuals with LD and that simultaneously visually highlight words as they are spoken are now available. In most cases the speed, pitch, and tone of voice can be set to accommodate individual preferences. The voice quality of speech synthesizers varies considerably, from more “human”- to more “mechanical”-sounding voices. In some instances, the more mechanical-sounding voices are actually more intelligible. There are also synthesizers available that provide the user with the opportunity to select a number of different voices (e.g., male, female, young, old).

Speech synthesis/screen review technology, when combined with a word processing program, may be helpful to students with written language deficits. (The systems discussed here should be differentiated from speech synthesis systems that are tied to specific word processing programs.) This is especially true for individuals who possess oral language skills that are superior to their written language abilities. For these persons, the ability to hear what they have written may enable them to catch errors in grammar, spelling, and punctuation that would otherwise go unrecognized. Having the auditory feedback also helps alert the user with LD to problems regarding the coherence and semantic integrity of his or her document.

The cost of commercially available speech synthesizers varies greatly, from approximately $100 to $1,000. Screen-reading programs appropriate for use with postsecondary students with LD generally run between $200 and $500 (in some instances the synthesizer and screen reader are bundled together). The amount of time needed to learn screen-reading programs also varies from product to product; however, most students with LD should be able to operate the program adequately within 1 hour.

Word Prediction. Word prediction software supports word processing programs by “predicting” the word a user is entering into the computer. Predictions are based on syntax and spelling, as well as frequency, redundancy, and recency factors. Some programs also “learn” the user’s word preferences. Typically, word prediction programs operate in the following manner. As the first letter of a word is typed, the program offers a list of words beginning with that letter. If the desired word appears in the list, the user can then choose the word (by pressing a corresponding number, or pointing and clicking) and the desired word will automatically be inserted into the sentence. If the desired word is not displayed, the user enters the second letter of the word and a new list appears with words beginning with those two letters. The user continues this process until the desired word is offered in the list. If the word is not included in the program’s database, it can be added for future use. After a word is chosen, the next word in the sentence is predicted, even before the first letter is typed. Again, if the desired word is not present, then the user continues to enter the letters until the word appears.

Word prediction can be helpful to postsecondary students with LD for several reasons. First, because the program minimizes the number of keystrokes it takes to enter a word, students with poor keyboarding skills may find these programs easier and faster to use than standard word processors. Second, the program acts as a compensatory spelling aid, as it automatically spells the word out, and the user need only recognize the word within the list. Additionally, because these programs utilize grammatical rules to predict words, students with syntactical deficits may find the programs helpful. Finally, students who have word-finding difficulties may discover that the word list acts as a prompt, cueing them to the appropriate word. It is important to realize that, in some instances, word prediction programs may actually interfere with the writing process (Cutler, 1991). The word list may be distracting, and having to stop and choose words may slow some students down, especially students who have significant difficulty in word recognition or who are proficient typists.

Word prediction programs are available as add-on programs that work in conjunction with standard word processors, and also as integrated word prediction/word processing software packages. Most word prediction programs require no more than an hour to learn and cost about $300.

Reading

Speech Synthesis. The benefits of speech synthesis systems are not limited to use with word processors. They may also be used to review materials written by others, including software tutorials, help systems, letters, reports, and online databases and information banks. These systems will read essentially any text on a computer screen. Some organizations, including Recordings for the Blind and the American Printing House for the Blind, are now producing “books on disk,” which make it possible for persons with LD to listen to text by means of a speech synthesis system. Persons with LD are eligible to receive services from these organizations. There are also several online electronic-text library collections available through the Internet that house large collections of classic works that have the potential to be read aloud by means of a speech synthesis/screen review system.

OCR/Speech Synthesis Systems. An OCR system might be thought of as a “reading machine.” OCR systems provide a means of directly inputting text/printed material (e.g., a page in a book, a letter) into a computer. Text is input by using a full-page flatbed scanner, in which a page of text is placed face down on the device (much like a copy machine), or a handheld scanner, which the user moves across a page of text (or down, depending on the particular system). “Book-edge” (designed for bound text) scanners and automatic document feeders are also
available for several systems. Once the text has been scanned into the computer, it can then be read back to the user by means of a speech synthesis/screen-reading system. This technology can be particularly helpful to individuals with LD who exhibit no difficulty comprehending spoken language (Gough & Tunner, 1986) yet have problems understanding language in the written form (Hughes & Smith, 1990).

OCR systems are of two basic types: stand-alone or PC based. Stand-alone (or "self-contained") systems have all components built into one device, including the scanner, OCR software/hardware, and speech synthesizer. Some stand-alone systems are portable, others are desktop units. The PC-based systems consist of a number of components that are hooked up to a PC. These components consist of a full-page (desktop) or handheld scanner, an OCR board and/or software, and a speech synthesizer. Several companies have designed systems with the individual with LD in mind (e.g., Xerox’s BookWise, Arkenstone’s Open Book, Kurzweil’s Omni), which simultaneously highlight words as they are spoken back by the system. The cost of OCR systems also varies widely, ranging in price from $2,000 to $5,000 (excluding the computer on the PC-based systems). It is important to keep in mind that the speed and accuracy of many of the low-end systems may be inadequate for the postsecondary student with LD. Several systems can be used quite effectively after only a couple of hours of instruction.

Variable Speech-Control Tape Recorders. Portable audiocassette recorders have been recommended by a number of authorities as a compensatory aid for postsecondary students with LD (Mangrum & Strichart, 1988; Scheiber & Talpers, 1985). Among the possibilities is the use of tape recorders for listening to books on audio-tape, which may help students with reading difficulties circumvent their disability by listening to prerecorded text (books, journals, newspapers). Prerecorded text is available from a number of sources, including The Library of Congress, Recordings for the Blind, and several private companies. Although tape recorders may be helpful to some students, they may present problems for individuals with LD who have difficulty processing auditory information at standard playback rates (McCroskey & Thompson, 1973). This problem can be alleviated by the use of variable speech-control (VSC) tape recorders, which, unlike conventional tape recorders (or units that simply have different record/playback speeds), enable the user to play back audio-taped material slower or faster than the rate at which it was initially recorded, without the loss of intelligibility, which is maintained by adjusting speed and pitch control levers. These devices enable the user to slow down prerecorded text by 25% without loss of intelligibility. VSC tape recorders range in price from approximately $100 to $200 and usually require no more than 30 minutes of training.

Organization/Memory

Personal Data Managers. Postsecondary students with LD often have difficulty remembering, organizing, and managing personal information (Mangrum & Strichart, 1988; Vogel, 1987). It may be a question of scheduling appointments; prioritizing activities; remembering important dates/deadlines; or recording/accessing names, addresses, and phone numbers. The use of personal data managers can compensate for difficulties in this area. Personal data managers are available as software programs as well as self-contained handheld units and allow the user to easily store and retrieve vast amounts of personal information. Data are input and retrieved via a keyboard/keypad and are displayed on a computer monitor or LCD display. Several newly released pocket-size data managers (e.g., Voice Organizer™, Voice It™) allow the user to enter and retrieve data by speaking into the device. Stored data are spoken back in the user’s own voice. Data managers have numerous capabilities and a diverse combination of functions. Typical features include monthly calendars, daily schedules/planners/appointments, clocks/alarms, memo files, to-do lists, name/address books, telephone directories (some with electronic dialers), and bankbooks/check registers/money managers. These products range in price from about $20 to $250 and require only 15 minutes to 2 hours to learn.

Free-Form Databases. Like personal data managers, free-form databases can also be valuable to individuals with organizational and/or memory problems. These software programs work with computers and might be thought of as “computerized Post-it™ note systems. Like abbreviation expanders, they are memory resident and can be activated while in a word processor or other program by simply pressing a “hot key.” Users can create their own notes, of any length, on any subject, in much the same way people use sticky notes, a notepad, or scraps of paper to jot down important information. Unlike a manual system, free-form databases enable the user to electronically store the notes in the computer’s memory, rather than on tiny pieces of paper that are easily misplaced.

Perhaps more important than how the information is stored is how it is retrieved. A note can be retrieved by typing in any piece or fragment of information contained in the note. For example, the note Carl Stevens, Advanced Electronics, Inc., 835 West Arden, Northridge, CA 91330, (818) 306-1954 could be brought up on the computer's screen by inputting any of the following information, including (but not limited to) “Carl,” “Advanced,” “West,” “North,” and “818.” The basic functions of a free-form database are relatively simple to learn and can be mastered in about 2 hours. Programs can be purchased for about $100.
Listening Aids

Personal FM Listening Systems. Research has indicated that some adults with LD have difficulty focusing auditorily on a speaker (Hasbrouck, 1980). Such difficulties may lead to misunderstanding or missing information presented during a classroom lecture or meeting. One device that may help students with LD focus on a speaker is a personal FM listening system. These technological aids consist of two basic components: a wireless transmitter with a microphone, and a receiver with a headset or earphone. For situations in which there is only one speaker (e.g., a professor in a classroom), the speaker wears the transmitter unit (about 2 in. × 3 in.), while the user wears the receiver unit (also about 2 in. × 3 in.). The transmitter and receiver are easily clipped to a belt or shirt pocket. The microphone is only about 1½ in. long and is easily clipped to clothing (e.g., a tie). When there are multiple speakers (e.g., during a meeting), an omnidirectional microphone enclosed in a small, stand-alone unit is placed in the center of the conversational interaction. Essentially, these systems carry the speaker’s voice directly from the speaker’s mouth to the listener’s ear. Volume is easily controlled by a dial on the receiver. These devices run on AA-size rechargeable or disposable batteries. The cost of such devices ranges from $300 to $600. It takes only a matter of minutes for a student with LD to learn to use these systems.

Tape Recorders. In addition to helping compensate for reading disabilities, tape recorders may also be useful to the student with listening difficulties (as well as memory problems). Tape recorders can be utilized to record classroom lectures, as either an alternative or a supplement to taking notes. This may be beneficial for students with LD who have listening difficulties because of either difficulty processing oral language or attentional disorders, because they can review lectures at a later date, listening to tapes as many times as necessary to comprehend the material. The ability to commit a lecture to permanent record may also aid students with other types of difficulties, including those who find it difficult to take notes and listen simultaneously, students with fine-motor dysfunction, and those with auditory memory problems. VSC tape recorders may be particularly helpful for reviewing taped material, as they enable the user to increase the speech rate (generally up to 100%) in order to reduce the amount of time it takes to “re-listen,” or, as previously discussed, reduce speech rates to more comprehensible levels.

Math

Talking Calculators. A talking calculator is simply a calculator with a speech synthesizer. When number, symbol, or operation keys are pressed, they are vocalized/spoken by a built-in speech synthesizer. In this way, the user receives simultaneous auditory feedback for checking the accuracy of visual–motor operations. Once a calculation has been made, the number can be read back via the synthesizer. This feature enables the user to double-check the answers being transferred from calculator to paper.

It is important to note that the speed at which calculations are performed may be problematic, because it takes longer to have operations spoken than displayed. Second, some students may experience “stimulus overload” when having to contend with both visual and auditory feedback. As with all technologies, individual profiles and preferences will have to be considered. Talking calculators take only about 15 minutes to master. Most talking calculators can be purchased for between $20 and $75. Bryant et al. (1993) stressed that postsecondary students with LD are likely to need scientific programmable calculators. Scientific programmable units with speech capabilities can cost as much as $650.

Research on the Effectiveness of Assistive Technology

There is a paucity of formal research regarding the effectiveness of assistive technology for postsecondary students with LD. Indications of effectiveness have been derived primarily from anecdotal reports and case studies (e.g., Brown, 1987; Bryant et al., 1993; Collins, 1990; Collins & Price, 1986; Cutler, 1990, 1991; Norris & Graef, 1990; Primus, 1990; Raskind & Scott, 1993). The limited research that has been conducted in this area is briefly reviewed below. Particular attention will be given to the authors’ federally funded research at CSUN.

Collins (1990) conducted a 3-year study on the impact of word processing on the writing performance of college students with LD in a required first-year writing course. Results suggested that the use of word processors helped the students complete the course at a rate similar to that of their nondisabled peers, achieve grades at least comparable to nondisabled peers, and improve their writing fluency. According to the researcher, the use of word processors also led to a significant reduction in writing anxiety among students with LD. Similarly, Primus (1990) studied the impact of word processing on the grades and grade-point averages (GPAs) of university students with LD. Results of that study indicated that freshman English grades and semester and cumulative grade-point averages were higher for students with LD who used word processors as compared to non–computer users with LD while they were taking freshman English. However, the researcher emphasized that the trend toward higher academic performance was not sustained throughout the participants’ academic careers.

McNaughton, Hughes, and Clark (1993) investigated the effect of five writing conditions on the spelling performance of college students with LD: handwriting, handwriting with a conventional print dictionary, handwriting with a...
ing with a handheld spell checker, word processing, and word processing with an integrated spell checker. Results indicated that the word processor with an integrated spell checker provided a statistically significant advantage over the other four conditions in the detection of spelling errors. The word processor with an integrated spell checker also showed a statistically significant advantage over handwriting and word processing (but not over the other conditions) in “correction activities.” The authors also reported that the word processor with spell checker demonstrated a significant advantage over handwriting and word processing, but not over handwriting in combination with a spell checker or conventional dictionary.

Elkind, Black, and Murray (1996) studied the use of optical character recognition with speech synthesis, as a compensatory tool for college students with dyslexia. The researchers reported that the technology enhanced reading rate and comprehension of most of the participants. Furthermore, the technology enabled the students to increase the length of time they were able to sustain attention to reading.

A comprehensive 3-year study on assistive technology for postsecondary students with LD was conducted by the Center on Disability at CSUN. In the first year of the project, the compensatory effectiveness of the following three technologies was investigated: (a) OCR/speech synthesis as a compensatory reading strategy, (b) speech synthesis/screen review as a compensatory proofreading strategy, and (c) speech recognition as a compensatory writing strategy. In Years 2 and 3 of the project, changes in academic outcomes, behaviors, and attitudes as a result of assistive technology use were studied. The cost effectiveness of these technologies was also investigated in the final year of the project. A brief description and the results of each phase of the project appear below (see Note 2).

During the first year of the study the immediate compensatory effectiveness of the technologies was investigated. OCR in conjunction with speech synthesis was evaluated as to its effectiveness in compensating for difficulties with reading comprehension. Thirty-seven postsecondary students with LD in the area of reading (see Note 3) were trained on the technologies and given the Formal Reading Inventory (Wiederholt, 1986) under three conditions: (a) reading the test silently without assistance; (b) having the test read aloud by a human reader; and (c) converting (scanning) the test into a computer document using an OCR system, then having it read aloud via a speech synthesis/screen review system. No differences were found in the means of standard scores across the three conditions. This was due to the fact that the technologies helped some readers while interfering with the performance of others. There was, however, a significant correlation (r = .001) between silent reading scores and scores obtained via the assistive technology; that is, the greater the disability in silent reading, the more the technology assisted the student to compensate for the difficulty. A similar but weaker correlation was found when the test was read aloud by a human reader (p > .01). These findings, taken together, suggest that the auditory presentation of text (whether by human voice or by computer) assisted less proficient readers with the decoding process (thus elevating their scores), but interfered with the more efficient silent reading processes for the proficient readers.

Speech synthesis/screen review was also assessed as to its effectiveness in increasing students' efficiency at proofreading written compositions. Thirty-four students with LD in the area of written language composed the first draft of an essay of approximately 500 words in length. The essay was divided into three equal parts, each of which was proofread under the following conditions: (a) without assistance, (b) having the essay section read aloud by a human reader, and (c) having the essay section read by the speech synthesis/screen review system. Students found significantly more errors overall using speech synthesis/screen review than when proofreading without assistance or proofreading while a human reader read the essay section aloud. Additionally, speech synthesis/screen review proved superior at assisting students in finding particular types of errors in comparison to proofreading without assistance (see Note 4). Typographical errors as well as errors in capitalization, spelling, and usage were found at a significantly higher rate using the technology. Having the essay section read aloud by a human reader proved significantly superior to proofreading without assistance for two types of errors, spelling and mechanical grammar errors. Finally, when comparing human readers to speech synthesis/screen review, human readers were superior to the technology at a significant level for one category—mechanical grammar errors (Raskind & Higgins, 1995).

Finally, speech recognition technology was evaluated as to its compensatory effectiveness at improving written composition skills. Twenty-nine postsecondary students with LD in the area of written language were trained on the speech recognition system and asked to write three essays under the following conditions: (a) without assistance (students could either handwrite or use a word processor to generate the “no assistance” essay); (b) dictating the essay to a human transcriber; and (c) using a speech recognition system. The essays were designed to emulate the Upper Division Written Proficiency Examination (WPE), a timed, holistically scored essay required by the university for a student to graduate. Significantly more students received a higher holistic score on the essay written using speech recognition than on the one written without assistance (p > .05). A post hoc analysis of the essays indicated that students used significantly more long words (words of seven or more letters) when using the equipment and, further, that the use of words with seven or more letters was positively

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correlated with better holistic scores at a significant level (p > .0001).

In Years 2 and 3 of the project, changes in academic outcomes, behaviors, and attitudes as a result of assistive technology use were studied. These results are reported briefly below. It is important to emphasize that this portion of the study was more descriptive than experimental. Data were derived from interviews, questionnaires and self-reports, supplemented where possible by computer log-on records, official reports, and databases that documented the use of services. It is acknowledged that many of the reported changes may have been due to factors other than those under investigation. It is also possible that the sample self-selected, with participants of particular “psychological constitutions” or having particular personality characteristics being drawn to participate in the study.

The 140 students who received training on the technology over the 3-year period showed several positive academic outcomes: (a) Participants significantly (p > .05) increased their GPAs for courses with heavy reading and/or composition requirements, whereas a matched control group did not (although these gains were not sufficient to increase overall GPAs so that they reached significance); (b) the university attrition rate for the 140 participants was only 1.4% over the 3-year period, compared to 34% for a matched group of students with LD who did not participate in training (and 48% for nondisabled students over 4 years; Office of the Chancellor, 1994); (c) although participants in the study showed numbers of withdrawals and incomplete similar to the matched group’s, they showed significantly higher rates of repeating the courses until a satisfactory grade was obtained; and (d) participants’ WPE first-time passage rate was 95%, compared to 50% passage rates for both the matched group and the population of LD students prior to the study, and a 75% overall passage rate for the general CSUN population.

Examination of log-on programs and responses to pre- and posttraining questionnaires revealed several changes in academic behaviors among the participants in the study. These changes included (a) a 78% increase in hours of use of assistive technology in general, which was accounted for primarily by greater use of word processing; (b) an increase among 73% of the participants in extending the use of word processors for academic purposes other than composition, such as note taking, organizing course content, outlining reading material, and managing time; (c) an increase among 90% of the participants in expanding the use of computers into nonacademic settings (e.g., employment, recreational/social); (d) increases in the use of assistive technologies not utilized in the study (e.g., VSC tape recorders, books on tape); and (e) an eightfold increase in the use of the three technologies under study by persons trained in the study.

An examination of databases documenting use of services through the computer access lab and of questionnaire responses also indicated that participation in the study and/or use of assistive technology was accompanied by changes in the use of compensatory strategies other than technological strategies, including (a) an initial tendency by newly identified students to increase their use of services offered by the CSUN Learning Disability Program and other campus services, followed by a decrease in the use of services by previously identified students, over the 3-year period; (b) an overall increase in independence, suggested by students’ less frequent reliance on family members, friends, classmates, and fellow employees to help them compensate for their disabilities; and (c) changed roles in study groups or informal study relationships with classmates, from “helpee” to “helper.”

Previous research on adults with LD (Adelman & Vogel, 1990; Gerber, Ginsberg, & Reiff, 1992; Spekman, Goldberg, & Herman, 1992) has indicated that successful adults understand the nature of their disability and tend to accept rather than deny the disability, to be users of technology, to use a variety of compensatory strategies in response to situational variables, to be self-advocates in terms of their disabilities, and to be active members of groups that advocate for persons with LD. Questionnaire responses indicated that attitudinal and affective changes had taken place as a result of training and/or participation in the study in the direction of the above cluster of attributes associated with successful adults: (a) Two thirds of the respondents reported having learned more about their strengths and weaknesses, and about LD in general, as a result of participation and training; (b) 80% of the students related that they felt better about themselves academically since discovering more about their disabilities through participation; (c) nearly half the respondents reported that computers had changed their lives for the better, allowing them to accomplish tasks they had previously been unable to do; (d) nearly a third reported that they “couldn’t have made it through” without the help of training on assistive technology; and (e) one third of the students reported alteration of their career goals to include working with other students with LD or related difficulties as a result of participation in the study.

Cost-effectiveness was evaluated for the technologies in Year 3 of the study. The analysis was prepared with regard to the costs that would be incurred by the service delivery point for assistive technology at CSUN, which is a well-established office of disabled student services with well-trained technical support staff and a history of attracting many student volunteers and adequate funding for several student assistants, to provide a variety of services for students with disabilities, including LD. Elements included in the analysis were the initial cost of equipment, equipment repair/maintenance, consumable supplies, and initial training and
supervisory/monitoring costs once students were trained (given current staffing and salary schedules). The estimate was then adjusted for projected increases in use of assistive technology services and other support services, on the basis of data gathered from the questionnaire given to students from the study and of log-on times taken from the computer access lab. The estimate was then compared to the cost of providing equivalent nontechnological services, such as transcribers, readers, tutors, counselors, and note takers, given current staffing and salary schedules. Two estimates were computed: (a) a minimal bottom-line cost estimate that covered the initial equipment purchases, initial training costs, and posttraining monitoring needs for the projected number of students likely to request services, given current turnover rates, and (b) a maximal estimate that, in addition to the costs listed under (a), included some student outreach efforts to previously identified students with LD, needs-assessment of the current population of students with LD, and the provision of specialized training based on that needs assessment (see Note 5). It was determined that the net savings for the ODDS for the minimal services was $320 per student per semester and $260 for the maximal services. The amount was then adjusted for projected increases in use of other services within ODDS and to other campus service providers, for a net benefit of approximately $310 for the minimal service provision and $234 for the maximal service provision, per student per semester.

It is important to stress that the evaluation of cost-effectiveness of any assistive technology is highly dependent on the context in which the analysis is conducted. Therefore, readers are cautioned not to generalize the results reported herein to other settings (e.g., employment, rehabilitation, etc.)—even other university/college settings, as even “comparable contexts” may vary markedly in regard to goals, purposes, and policy regarding the delivery of assistive technology, other support services, the location within the postsecondary institution of the assistive technology delivery point (e.g., office of disabled student services vs. centralized computing center), and budgetary policy (e.g., soft vs. hard funding for technological training and/or equipment purchases).

Summary and Recommendations

The practice of providing assistive technology to postsecondary students with LD has had a very short history. Although assistive technology LD support services are growing, considerable investigation, exploration, and experience is still needed to determine which service delivery models, specific services, and technologies are the most appropriate for meeting the needs of individual institutions, LD support service programs, and students with LD. Additionally, although numerous technologies are now available to help postsecondary students with LD compensate for a variety of difficulties, there is a paucity of research to support their efficacy. Only a limited number of studies have been conducted on a narrow range of technologies.

Although research in the area of assistive technology for postsecondary students with LD is quite limited, collective results are suggestive of a number of general conclusions: (a) Select assistive technologies have been found effective for some students in compensating for specific deficits in such areas as writing and reading; (b) a technology that is beneficial for one individual with LD could be counterproductive for another; (c) it is unclear whether the use of assistive technology leads to improved academic outcomes (e.g., improved overall GPA); (d) low-tech or even “no tech” solutions may be more effective than high-tech assistive technology; (e) specific types of technology (e.g., speech synthesis) may be helpful in compensating for one area of difficulty (e.g., proofreading) but not necessarily for another (e.g., reading); (f) the fact that an assistive technology has compensatory value does not guarantee that it will be cost- or time-effective; (g) a technology may be more effective than alternative strategies in helping one specific area of skill deficit (e.g., speech synthesis in catching usage errors) but not others (e.g., locating grammar–mechanical errors); and (h) some assistive technologies seem to have a positive behavioral and/or psychological/attitudinal effect on specific students.

The use of assistive technology as a means to help postsecondary students with LD compensate for their difficulties and to enhance their academic success looks promising. However, to ensure that the full benefits of assistive technology are achieved, concerted effort will have to be made to conduct research regarding (a) the compensatory effectiveness of select technologies for specific difficulties (and how these technological interventions compare to nontechnological strategies); (b) the extent to which specific contexts influence the compensatory effectiveness of select technologies; (c) the possible relationship between assistive technology use and academic outcomes, including grades/performance in specific courses, course withdrawals and incompletes, grade-point averages, and retention/graduation rates; (d) the potential behavioral and/or psychological benefits of assistive technology, including changes in levels of independence, perseverance, attitudes toward academic tasks, self-esteem, and self-understanding; (e) the possible social consequences of assistive technology use, including changes in establishing and sustaining friendships and levels and types of social participation; (f) the long-term effects of assistive technology use; (g) valid and reliable assessment practices for determining which students will benefit from assistive technology, and ensuring the best possible match between the student, technology, task, and context; (h) the cost-effectiveness of assistive technology as compared to alter-
native compensatory strategies in light of the costs associated with specific products, maintenance, consumable supplies, technical support, training, and personnel; and (i) the effectiveness of different service delivery models/practices relative to such factors as the coordinating department, the types and location of technology, personnel, training, technical support, and funding.

To ensure that research will ultimately benefit postsecondary students with LD, mechanisms are needed to close the gap between research and practice, ensuring that what is validated in research is effectively implemented in the postsecondary setting. Translating research into practice is not simply a matter of disseminating research results to postsecondary institutions, but, rather, necessitates that the institutions themselves (to the extent possible) play an active role in the research process. Such participation requires ongoing collaboration and communication between researchers, service providers, administrators, faculty, and students with LD.

Effective implementation also demands that postsecondary institutions have a well-defined, comprehensive, and systematic plan for assistive technology service delivery. This plan needs to clearly delineate (a) goals and objectives; (b) the office/department responsible for coordinating service delivery; (c) the personnel responsible for implementing the plan; (d) service eligibility criteria; (e) timelines for completion; (f) the specific technologies needed, including modification of existing technologies and systems (e.g., library information systems, e-mail, the Internet); (g) the location(s) of the technology; (h) the hours when the technology is available for student use; (i) the times when training/support is available; (j) training procedures and content; (k) a technical support and maintenance plan; (l) funding mechanisms for initial and continued financial support; (m) procedures for interdepartmental coordination; and (n) a plan for evaluating the efficacy of the service delivery system over time.

Consideration should also be given to (a) initial and ongoing training/information dissemination to faculty, support personnel, administrators, and persons with LD to promote awareness of assistive technology (and related federal regulations); (2) the strategies necessary to ensure that support service providers and students with LD are kept abreast of current technologies, assessment practices, service delivery strategies, legislation, funding opportunities, and research (which would necessitate ongoing contact with manufacturers, conference participation, training, and literature review); (3) the procedures required to foster collaboration with technology manufacturers in order to identify and develop/modify appropriate technologies for individuals with LD; and (4) the safeguards required for ensuring that service delivery is in accord with federal regulations regarding postsecondary institutions and assistive technology.

In conclusion, assistive technology holds great promise for helping postsecondary students with LD reach their full potential. However, only through continued research and carefully planned and executed service delivery systems will this promise be realized. This is our challenge; this is our responsibility.

ABOUT THE AUTHORS
Marshall H. Raskind, PhD, is director of research at the Frostig Center. His research interests are in the areas of technology, as well as learning disabilities across the lifespan. Eleanor L. Higgins, PhD, is a research associate at the Frostig Center. She is currently conducting longitudinal research on persons with learning disabilities, as well as research in the area of technology and language. Address: Marshall H. Raskind, Frostig Center, 971 N. Altadena Dr., Pasadena, CA 91107.

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NOTES
1. This section draws heavily (with permission) from a previous publication—Raskind and Scott (1993)—but is updated to reflect the most current technological developments.
3. Students were selected from the CSUN Learning Disability Program and identified as LD in accord with the criteria of the California State University Chancellor’s Office.
4. Error categories included capitalization, punctuation, spelling, usage, grammar/mechanical, grammar/global, typographical, content/organization, and literary style.
5. The maximal amount was based on the actual outreach, needs assessment, and service provision costs that were incurred during Years 2 and 3 of the study. The needs assessment conducted in Year 2 revealed that two areas of need were salient to participants in the study—passage of the WPE, and instruction on how to write a term paper. Two “minicourses” entitled “Writing a Term Paper Using Technology” and “Passing the WPE Using Technology” were developed. Flyers were sent out to all students with learning disabilities each semester. Sixty students responded and subsequently participated in the minicourses.

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