Emerging Technologies and Cognitive Disability

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Despite the potential of emerging technologies to assist persons with cognitive disabilities, significant practical impediments remain to be overcome in commercialization, consumer abandonment, and in the design and development of useful products.

Barriers also exist in terms of the financial and organizational feasibility of specific envisioned products, and their limited potential to reach the consumer market. Innovative engineering approaches, effective needs analysis, user-centered design, and rapid evolutionary development are essential to ensure that technically feasible products meet the real needs of persons with cognitive disabilities.

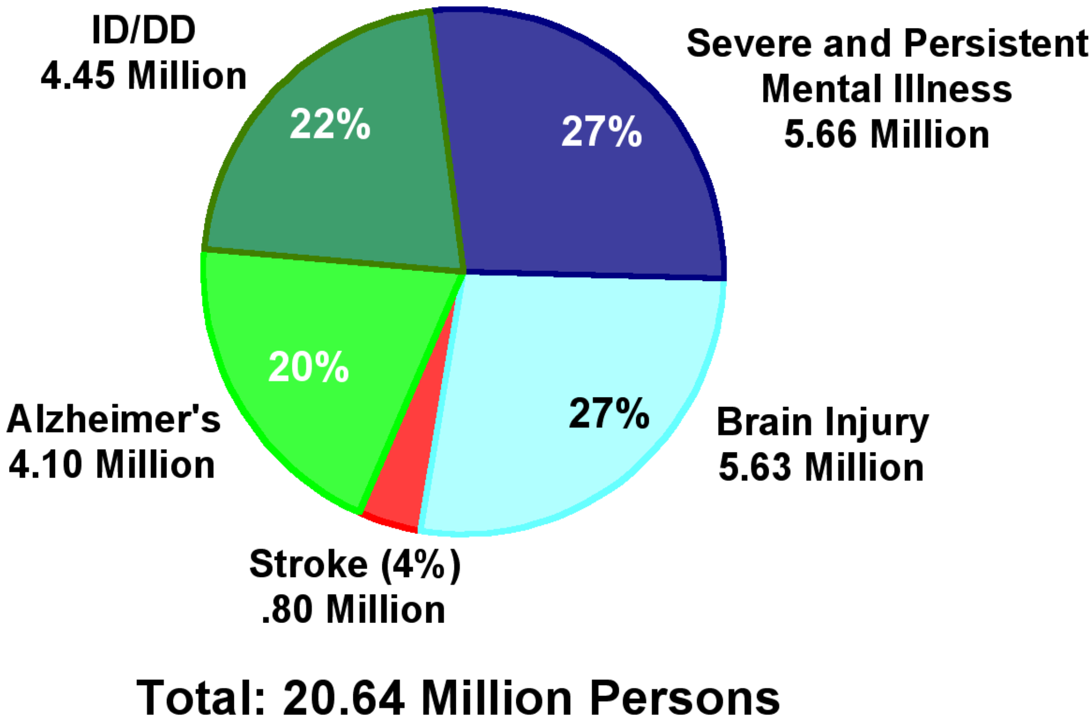
Efforts must be made by advocates, designers and manufacturers to promote better integration of future software and hardware systems so that forthcoming iterations of personal support technologies and assisted care systems technologies do not quickly become obsolete. They will need to operate seamlessly across multiple real-world environments in the home, school, community, and workplace.

Cognitive disability entails a substantial limitation in one's capacity to think, including conceptualizing, planning, and sequencing thoughts and actions, remembering, interpreting subtle social cues, and understanding numbers and symbols. Cognitive disabilities include intellectual disabilities and can also stem from brain injury, Alzheimer's Disease and other dementias, severe and persistent mental illness, and, in some cases, stroke (see Figure 1). More than 20 million persons in the United States have a cognitive disability -- and the number of individuals with cognitive disabilities such as Alzheimer's disease is expected to increase rapidly as the nation's population ages (Braddock, 2001).

Utilization of Technology

Many persons with cognitive disabilities utilize assistive technologies to enhance functioning in activities of daily living, control of the environment, positioning and seating, vision, hearing, recreation, mobility, reading, learning and studying, math, motor aspects of writing, composition of written material, communication, and computer access. Technologies used range from low-tech devices, such as pictorial communication boards or adapted eating utensils, to high-tech devices including adapted software and voice output devices with speech synthesis (Technology and Media Division, 2003).

Figure 1: Cognititve Disability in the United States



An assistive technology device is defined in the Technology Related Assistance for Individuals with Disabilities Act of 1988 (Pub. L. 100-407) and the Assistive Technology Act of 1998 (Pub. L. 105-394), as "any item, piece of equipment, or product system, whether acquired commercially, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Title 29, Chapter 31, § 3002(a)(3)). The term assistive technology service is defined in the Technology Related Assistance for Individuals with Disabilities Act of 1988 (Pub. L. 100-407) and the Assistive Technology Act of 1998 (Pub. L. 105-394), as "any service that directly assists an individual with a disability in the selection, acquisition, or use, of an assistive technology device" (Title 29, Chapter 31, § 3002(a)(4)).

To date, much of the research on assistive technologies for persons with cognitive disabilities has focused on the benefits of augmentative and alternative communication (AAC) aids. "In the broadest sense, the goal of AAC interventions is to assist individuals with severe communication disorders to become communicatively competent today in order to meet their current communication needs and to prepare them to be communicatively competent tomorrow in order to meet their future communication needs" (Mirenda, 2001, p. 142). AAC research has helped disprove the previously widely held belief that persons with significant levels of cognitive disabilities could not benefit enough from communication devices to justify the cost (Light, Roberts, Dimarco, & Greiner, 1998; McNaughton, Light, & Arnold, 2002; Romski & Sevcik, 1997; Turner, 1986, cited in Romski & Sevcik, 2000). Speech recognition and output technology, in particular, has been shown to greatly enhance the participation of individuals with disabilities in educational and other daily activities (Cavalier & Brown, 1998; Lancioni, O'Reilly, & Basili, 2001; Mechling, Gast, & Langone, 2002; Romski, Sevcik, & Adamson, 1999).

Confluence of Advances in Technology

Until recently, when the term technology was used in conjunction with cognitive disability, it most likely referred to an assistive technology device, such as one for augmentative and alternative communication or a switch to control the environment. State-of-the-art technological advances in computer science, engineering, communications, rehabilitative science, and microelectronics have rarely been adapted for people with cognitive disabilities. However, the number of people with cognitive disabilities is expected to increase rapidly in future years, and as a result there is increased interest in developing and marketing new technologies for people with cognitive disabilities. Cognitive technologies have the potential to help persons with cognitive disabilities, and those with age-related cognitive decline, to achieve greater independence, productivity, and quality of life (Bowles, 2003; Eisenberg, 2002; Hammel, 2000; Hammel, Lai, & Heller, 2002; Merritt 2003).

Product engineering is evolving from stand-alone devices and applications to distributed, connected, integrated, and multi-technology systems (Kurzweil, 1990, 1999, 2002). Electronic products are becoming *smart* and software systems are becoming adaptive and personalized. The movement toward smaller, easier to use, micro-technologies, with larger-scale integration, increased performance, and reduced price not only benefits the general population, but also has the potential to benefit those with cognitive disabilities. Three arenas of technology advancement in cognitive disability are described below: personal support technologies, assisted care systems technologies, and virtual technologies.

Personal Support Technologies

Personal Digital Assistants

Personal support technologies (PST), such as personal digital assistants (PDAs), have the ability to greatly enhance the independence, productivity, and quality of life of persons with cognitive disabilities (Bergman, 2002; Grealy, Johnson, & Rushton, 1999; Hart, Hawkey, & Whyte, 2002). For example, parents or caregivers can pre-program a PDA or desktop software with educational, vocational, or daily living tasks to prompt individuals with cognitive disabilities to perform a wide variety of well-defined vocational and independent living tasks (Davies, Stock, & Wehmeyer, 2002a). Specialized PDA software is currently available for enabling individuals with developmental and other cognitive disabilities to manage personal schedules with much greater independence (Davies, Stock, & Wehmeyer, 2002b), for helping direct individuals during their work tasks (Davies, Stock, & Wehmeyer, 2002a; Furniss et al., 2001; Furniss & Ward, 1999), and for assisting with activities of daily living (Lancioni, O'Reilly, Seedhouse, Furniss, & Cunha, 2000; Lancioni, O'Reilly, Van den Hof, Seedhouse, & Rocha, 1999). PDAs can also interface with wireless communication protocols to track and monitor an individual's daily activities, and provide prompts to the individual as needed to complete educational or work tasks (Furniss et al., 2001; Kautz et al., 2001; O'Hara, Seagriff-Curtin, Davies, & Stock, 2002). PDA technology has also benefitted individuals with traumatic brain injury (Cole, 1999) and communication disorders (McDonough, 2002).

Computer Assisted Learning and Communication

Other personal support technologies include specialized computer training programs (Davies, Stock, Wehmeyer, 2003, 2004), voice interfaces (Barker, 2002), picture-based email programs, and adapted Web browsers such as WebTrek (Davies, Stock, Wehmeyer, 2001). Wearable computers can also assist students with cognitive disabilities. For example, a wearable data glove has been developed by an engineering student at the University of Colorado that translates American Sign Language and transmits this information wirelessly to an electronic display (Patterson, 2002).

Access to personal support technologies can benefit individuals in the classroom to remain on task, remind them of pending assignments, and provide access to information on the computer or the Internet. The effectiveness of computer-based learning techniques for students with cognitive disabilities has been well documented (Alcade, Navarro, Marchena, & Ruiz, 1998; Bernard-Opitz, Sriram, & Nakhoda-Sapuan, 2001; Blischak & Schlosser, 2003; Scruggs & Mastropieri, 1997). [See Wehmeyer et al. this issue for a comprehensive review of the research conducted on technology use by students with intellectual disabilities].

Despite the benefits to be gained, however, studies indicate access to computers and the Internet for persons with cognitive disabilities in the classroom and at home lags behind access for persons without disabilities (Abbott & Cribb, 2001; Aspinall & Hegarty, 2001; Johnson & Hegarty, 2003; Kaye, 2000). Almost 60% of persons with disabilities have never used a computer, compared to less than 25% of persons without disabilities (Abramson, 2000). Less than 10% of persons with disabilities have access to the Internet, compared to 38% of persons without disabilities. A discrepancy also exists in computer ownership. Less than 24% of people with disabilities own a computer, compared to over 50% of persons without disabilities (Kaye, 2000). The rates of access for persons with cognitive disabilities are undoubtedly even lower than the above-cited statistics, which apply generally to persons with disabilities. Some researchers, however, posit that with advances in computer power and declining costs, increasing numbers of students with disabilities will have appropriate access to necessary technologies (Hasselbring, 2001). However, as noted by Tinker (2001), education tends to follow well behind other sectors of society in terms of technology utilization. In addition, this problem can be exacerbated in special education because it comprises a small market relative to general education.

Universal Design

Universal design principles are necessary to ensure that persons with cognitive disabilities are able to utilize common technologies available to the general public. Universal design intends that products -- especially software and computers -- provide an interface that is suitable for all potential users, including persons with disabilities. Web standards, such as User Agent Accessibility Guidelines (Festa, 2002), federal regulations - such as Section 508, and public/private initiatives, such as the World Wide Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C), promote access to software and the internet for people with disabilities. But how does one define accessibility? Elbert Johns, Director of TheArcLink, (as cited in Rizzolo, Bell, Braddock, Hewitt, & Brown, in press) has suggested the importance of clearly defining the principal components of accessibility as this term pertains to people with intellectual and developmental disabilities and their use of information technology. Specifically, he notes that for information to be accessible to a person with an intellectual disability, it must (a) decrease the dependence on rote memory as a tool for recalling information, (b) use as many complementary formats as possible [visual, audio, multi-graphic], (c) reduce the need for the recipient to utilize complex organizational skills for comprehension, and (d) be presented in a vocabulary or reading level that approximates the level of the recipient. More intuitive, user-centered, computing interfaces are necessary to increase accessibility and empower persons with cognitive disabilities to use common technologies such as the Internet and personal computers.

Assisted Care Systems Technology

Another area of emerging technology for persons with cognitive disabilities is assisted care systems technology. These technologies are designed to assist caregivers of individuals with cognitive disabilities, and can range from simple monitoring devices to complex assisted care systems (ACS) integrated into the infrastructure of a building. These emerging technologies can assist in promoting the independence and health of persons with disabilities -- including persons with cognitive disabilities-- while maintaining safety.

Smart Houses

One example of an assisted care system is the *smart* home. Smart homes and rooms (Pentland, 1996) combine tracking technology and environmental control to provide robust prompting, including environmental cues such as adjusted lights (Lancioni & Oliva, 1999), and simplified operation of household systems. Many companies, such as Microsoft, Honeywell, and Intel, and universities such as MIT and Georgia Tech, are researching smart home technology as beneficial examples of ubiquitous computing. One company is already developing and using smart home technology to help care for residents with early-stage Alzheimer's disease in assisted living facilities (Elite Care, 2001). Research at the University of Colorado at Boulder is also underway to apply similar smart supports technology to community and family-based settings for persons with developmental disabilities (Taylor, 2003).

Residential assisted care systems integrate indoor/outdoor tracking systems, bio-sensors, building automation, databases, computer networks, and eventually, learning algorithms. Assisted care systems could provide numerous benefits for persons with cognitive disabilities, their families, and caregivers. For example, tracking systems can provide feedback to direct support employees and relatives on daily living activities (Elite Care, 2002). Pattern-recognition and learning software can be used to alert direct support employees of impending risks or adverse events, including social isolation and abnormal behavior (Elite Care, 2002). Building automation can simplify or control operation of household systems, including disabling an appliance or unlocking a door when a resident reaches their room. Though the research to date has focused on how these systems can promote independence in residential settings, much of the technology has the potential to be applied to other environments including the work site and the classroom.

Smart Transportation/Tracking Technology

Another example of smart technology is the smart transportation system. This system can assist persons with cognitive disabilities with mass transportation by utilizing wireless technologies and personal digital assistance devices such as the global positioning system (GPS) (Fischer & Sullivan, 2002). Travelers can be alerted when their GPS-equipped bus is arriving, and caregivers can be notified if the traveler has boarded the wrong bus. Problems with transportation have been cited as one of the most pressing barriers to the full integration of persons with disabilities into community life (New Freedom Initiative, 2001). The availability of reliable and safe transportation options can be an essential precursor to the successful transition from school to work.

Tracking technology is also a potentially useful ACS strategy to address wandering. Over 50% of respondents in a survey by the National Down Syndrome Society (2001) identified wandering as a significant problem. Many of the respondents indicated that wandering behavior occurred at night. Companies have developed both personal devices and home-based systems to address this need (Digital Angel, 2002). Utilizing GPS or local tracking data, monitoring devices can also alert caregivers in the event of a fall or unusual activity, or help locate persons who wander.

Assisted care systems can also be used to monitor the health of persons with cognitive disabilities. For example, ACS can integrate data from devices that passively monitor biomedical signs (e.g., smart bed sheets or more conventional vital signs monitors). With novel algorithms to estimate health states (Pavel, 2002), ACS can provide an unobtrusive, continuous picture of an individual's health. Research is also being conducted involving more focused, personal health advisory systems for the home (Fauchet, 2002). In the classroom, these systems could assist educational staff to monitor the health status of individuals with complex disabilities in an unobtrusive way during school hours.

Personal Robots

Robots have also emerged as a novel way to supplement the role of caregivers (Dario, Guglielmelli, Laschi, & Teti, 1999; Excell, 2004). Researchers at Carnegie Mellon and the University of Pittsburgh have developed a nurse robot (Nursebot) to assist elders with activities of daily living including prompts to perform certain tasks and medication administration (Rotstein, 2004; Stresing, 2003). The role of robots in the provision of care to the elderly and persons with cognitive disabilities will increase as the general population ages, the need for long-term care increases, and the pool of potential caregivers declines. Analysis of data from the National Long Term Care Survey showed that utilization of assistive technologies was associated with fewer hours of personal assistance (Hoenig, Taylor, & Sloan, 2003). Future research should investigate the role these technological assistants can play in the school environment.

Virtual Technologies

A third emerging arena of technologies for persons with cognitive disabilities is virtual technologies. Virtual technologies attempt to create an experience that simulates an actual experience, and have the potential to promote the participation of persons with disabilities in educational and community activities. Virtual environments (VEs) range from desktop VEs operating on a personal computer to full-immersion, three-dimensional situations.

Studies have documented the benefits of providing instruction to students with cognitive disabilities using virtual technologies and computer-based simulations (Akhutina et al., 2003; Lannen, Brown, & Powell, 2002; Cromby, Standen, & Brown, 1996). For example, researchers at the University of Colorado have created "full-bodied three-dimensional animated characters" capable of engaging in "natural face-to-face conversational interaction with users"(Ma, Yan, & Cole, 2004, p. 1) . The animated character software program assists children with speech and reading difficulties to interact with animated characters to improve speech and language skills, and is currently available in English, Spanish, and other languages (Ma et al., 2004).

The use of virtual reality for educating persons with cognitive disabilities can overcome barriers of real-world training situations such as cost, safety and accessibility (Cromby et al., 1996). Researchers have utilized virtual technologies to provide instruction in community-based activities such as shopping, social interactions, and safety (Brown & Standen, 1999; Langone, Clees, Rieber, & Matzko, 2003). Use of virtual technologies in the classroom can be extremely motivating to students, can make abstract learning concepts more concrete, allow students to progress through an experience at their own pace, and encourage active participation rather than passive observation (Pantelidis, 1995). Furthermore, skills learned in virtual environments have been shown to successfully transfer to real world situations (Standen, Brown, & Cromby, 2001; Standen, Cromby, & Brown, 1997). Virtual environments have also been used to mentor adults with cognitive disabilities and the elderly (Brown & Standen, 1999).

Virtual technologies are also being used to promote the health and well being of individuals with disabilities. Researchers at the University of Colorado and the University of Illinois at Chicago are developing engaging and motivating exercise opportunities for persons with disabilities in their own homes through virtual exercise environments. This study investigated whether virtual environments could increase distributed exercise participation by addressing frequently reported transportation barriers (Bennett, Bodine, Mulligan, and Lightner, 2002). This project has the potential to assist individuals with cognitive disabilities living in dispersed living environments to achieve improved health outcomes (Rimmer, Braddock, & Pitetti, 1996). Future research and development in this area should investigate the feasibility of incorporating this technology into the school system to provide virtual exercise opportunities to persons with disabilities that adapt to the abilities of each individual. Virtual technology could track exercise goals for each student and allow opportunities for students to participate in virtual competitions with others with similar competencies.

Conclusion

Due to continuing advances in microprocessor speed and processing capacity, computing power is progressing at an exponential rate. It literally doubles every 12-18 months (Kurzweil, 1999). The rapid rate of progress in computing power suggests that personal support, assisted care, and virtual technologies will progress rapidly over the next decade, becoming substantially more personalized. There are also positive signs that the assistive technology industry is growing. According to a U.S. Department of Commerce survey (2003), 359 companies manufacturing assistive technologies reported sales of $2.87 billion in 1999, up

21.8% from 1997 sales. Market projections suggest that emerging neuroscience technologies, like brain-machine interfaces permitting brain control of robot arms or computers, will be a $3.6 billion industry by 2008 (Cavuoto, 2004). Advances in cognitive neuroprostheses (Horch, & Dhillon, 2004), stem cell transplantation (http://stemcells.nih.gov/index.asp), and therapeutic cloning in South Korea (Hwang et al., 2004), hold exceptional promise to benefit persons with cognitive disabilities, and with time, may significantly improve function in disorders such as Alzheimer's, Down syndrome, and Parkinson's disease.

Despite the potential of emerging technologies to assist persons with cognitive disabilities, there are significant practical impediments to be overcome in commercialization, consumer abandonment, and in the design and development of useful products. For example, existing barriers to widespread commercialization of emerging technologies include regulatory burdens imposed by the FDA and the economically disadvantaged status of many persons with cognitive disabilities -- combined with limited private insurance and Medicaid/Medicare coverage and payment policies (US Department of Commerce, 2003).

Barriers also exist in terms of the financial and organizational feasibility of specific envisioned products, and their limited potential to reach the consumer market. Innovative engineering approaches, effective needs analysis, user-centered design, and rapid evolutionary development are essential to ensure that technically feasible products meet the real needs of persons with cognitive disabilities. The obsolescence of most technological devices after only a few years presents a significant barrier to persons with cognitive disabilities. Efforts must be made by advocates, designers and manufacturers to promote better integration of future software and hardware systems so that forthcoming iterations of personal support technologies and assisted care systems technologies do not quickly become obsolete. They will need to operate seamlessly across multiple real-world environments in the home, school, community, and workplace.

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