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Editors

Assistive Technologies for People with Diverse Abilities

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Assistive Technologies for People with Diverse Abilities

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For our wives
Gabriella and Judy

Preface

This book examines the use of assistive technology by a variety of individuals, many of whom experience difficulties in their daily lives because of, for example, acquired brain damage, autism, communication and motor impairment, and Alzheimer's disease. The number of individuals comprising these groups is slowly increasing due to factors such as longer life expectancy, higher posttraumatic survival rate, and lower neonatal mortality. As such, families and professionals largely agree there is an increased need for intervention programs to improve the quality of life of these individuals. While the type of intervention may vary, there is a trend toward increased use of assistive technology to effectively and cost-efficiently manage the proposed interventions. For example, microswitch-aided programs are typically more beneficial and affordable than simple staff-aided stimulation in increasing the activity and self-determination of people with motor and intellectual impairments. Similarly, programs based on speech-generating devices or personal data assistants are considered better and less expensive than direct intervention strategies for active communication and memory.

The aim of the book is to provide a current review of research and intervention strategies for nine groups of people: individuals with acquired brain damage, college students with attention and learning difficulties, people with communication impairment, people with visual impairment and blindness, people with autism spectrum disorders, people with behavioral and occupational disorders, people with Alzheimer's disease, people with learning disabilities, and people with severe/profound and multiple intellectual and motor or sensory-motor impairments. There is a chapter dedicated to each group, which provides information regarding (a) individuals' general characteristics, with personal and social needs to be met; (b) technology available; (c) technology-aided programs assessed in the literature; (d) outcomes of the programs; and (e) discussion of the outcomes and implications for future research and intervention programs. The overall aim of this book is to provide a highly informative and practical outlook of typical issues and potential solutions afforded by technology-aided programs. The authors provide evidence-based guidelines across fields to support initiatives and increase practitioners' probability of success.

This book represents the effort of many authors. As editors, we would like to thank them for their scientific contributions and their positive attitudes throughout the book development process. We would also like to thank the researchers and technical experts (engineers) who helped us better understand the problems experienced by persons with diverse abilities and the technology-aided strategies that might be used to help them, and the organizations that supported our research initiatives. With regard to the researchers and technical experts, we would like to acknowledge the extensive contribution of Doretta Oliva, Domenico Bellini, Sandro Bracalente, and Gianluigi Montironi. With regard to the organizations, we would like to emphasize the lasting positive role of the Lega F. D'Oro Research Center, Osimo (Italy), the University of Bari (Italy), ONE Research Institute, Raleigh, North Carolina (USA), and the Medical College of Georgia, Georgia Regents University, Augusta, Georgia (USA).

Contents

About the Editors

Giulio E. Lancioni, Ph.D., is Professor in the Department of Neuroscience and Sense Organs, University of Bari, Italy. Prior to this position, he spent many years at the Department of Psychology, University of Leiden, The Netherlands. His research interests include development and assessment of assistive technologies, training of social and occupational skills, and evaluation of strategies for examining preference and choice with individuals with severe/profound intellectual and multiple disabilities (including post-coma persons in a minimally conscious state and persons with Alzheimer's disease). He has published widely in these areas and serves on the editorial board of several international journals concerned with these topics.

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Chapter 1
Assistive Technologies for Improving Quality of Life

Giulio E. Lancioni and Nirbhay N. Singh

Introduction

In our previous book, *Assistive technology: Interventions for individuals with severe/profound and multiple disabilities*, we discussed assistive technology as commercial or customized devices that help people to reduce the impact of their disability on daily functioning and to achieve a better quality of life (Lancioni et al. 2013a). These devices can be as simple as laminated picture cards that can be exchanged as a form of communication by people who have no or minimal expressive language, or photo albums that serve as memory aids for those with early stage dementia. On the other hand, they could be as sophisticated as smartphones, iProducts, and computer-based eye gaze devices that enable alternative modes of communication by people who otherwise would have no means of communication due to their physical and/or cognitive limitations. Indeed, it is now possible that if a person can move just one muscle in her body we can customize a device to make use of that muscle to enable communication and initiate social interaction. Regardless of whether a device is simple or sophisticated, or the nature of the person's disability, the purpose of assistive technology is to improve the individual's quality of life by enabling increased independence.

The concept of quality of life has evolved from a focus on general well-being to physical, emotional, and social well-being, and more recently to specific domains of life for specific groups of people. This has led to such a proliferation of definitions of quality of life that Hughes et al. (1995) found 44 definitions and 1,243 tools to measure quality of life in only 87 research studies. Of course, both the number of definitions and the tools to measure quality of life have increased

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geometrically since the Hughes et al. study was published. There is international consensus that there are eight core domains of quality of life including emotional well-being, interpersonal relationships, material well-being, personal development, physical well-being, self-determination, social inclusion, and rights (Schalock et al. 2002; Wang et al. 2010). Assistive technology can enhance the quality of life of individuals with diverse abilities in all of these domains, but probably not in all domains for all people.

This book provides a review of the research literature and current thinking regarding assistive technology and how its use can enhance the quality of life of people with diverse abilities. A brief synopsis of the topics covered in this book is presented below.

Acquired Brain Injury

Acquired Brain Injury (ABI) refers to brain damage after birth that may be caused by infection, substance abuse, brain tumors, poisoning, encephalopathy, ischemia, and stroke, or by closed or penetrating head injury. It is estimated that over 5 million people in the United States have ABI and require continuous support and assistance in completing daily tasks, particularly in the areas of cognition, physical mobility, adaptive behaviors, and engagement in socially appropriate behavior (Flanagan et al. 2008) at a cost of up to $60 billion annually (Finkelstein et al. 2006). ABI negatively affects an individual's social relationships, educational attainment, employability, and community life (Ross et al. 2011). Individuals who sustain ABI may evidence personality changes as well as loss of cognitive skills such as memory or decision making, loss of communication skills, decreased mobility, loss of adaptive and leisure skills, and loss of vocational skills (U.S. Department of Health and Human Services 1999).

In Chap. 2, Rispoli and colleagues review assistive technologies that have been used in the rehabilitation of people with ABI, especially for cognition, communication, leisure, and vocational skills. People with ABI often exhibit deficits in memory such as remembering to take their medication, and executive functioning such as scheduling and keeping appointments (de Joode et al. 2010; Wilson et al. 2001). While there are no actual restorative treatments, assistive technology can be used as compensatory treatment for cognitive skill deficits. Thus, low-tech devices, such as an alarm can be used to remind the person to take medication, and calendars, "to do" lists, sticky notes, daily planners, and memory notebooks can be used to compensate for memory deficits (De Pompei et al. 2008; McKerracher et al. 2005). Furthermore, high-tech devices can be used to actively remind the person of the task to be completed. These include familiar electronic devices such as pagers, cell phones, personal digital assistants (PDAs), electronic diaries, instant messaging programs, and Internet calendars (Bergquist et al. 2009; McDonald et al. 2011). Other high-tech devices include electronic memory aids, handheld electronic devices, Internet resources, and ABI-specific devices such as alphanumeric pager prompting systems, voice prompting systems, and wristwatch and TV prompting systems.

Given that sustaining an ABI may disrupt a person's functional communication system, assistive technology in the form of Augmentative and Alternative Communication (AAC) can be used as alternative communication strategies (see Chap. 4 for details). As noted by Rispoli and colleagues in Chap. 2, AAC has been used to address receptive language skills that involve understanding what is heard or read, expressive language skills (e.g., labeling, requesting, or commenting), and pragmatic skills needed in social interactions and conversations.

People who sustain severe ABI often experience difficultly in independently engaging in leisure activities due to memory or other cognitive deficits, physical limitations, or communication deficits. For such individuals, high-tech assistive technology can be used to enhance engagement in leisure skills (see Lancioni et al. 2010 for a recent review). Some of these high-tech supports for leisure skills include microswitches, virtual reality, prompting systems, and adapted household equipment.

People with ABI have a much higher rate of unemployment (about 42 %) than those in the general population (about 9 %). While some of this discrepancy in unemployment rate can be explained in terms of reluctance of employers to make necessary accommodations for a prospective worker who is disabled, characteristics of the individual stemming from the ABI may also contribute to low employment rates. For example, these individuals may not be able to work the required hours due to post-injury fatigue, or may have coordination, balance, and mobility problems that limit choice of available work, or may have memory deficits such that they cannot remember the task at hand. For some of these individuals, commercial or customized low-tech and high-tech assistive technologies may provide compensatory supports to obtain and retain employment of their choice. Rispoli and colleagues discuss many ways by which people with ABI can enhance the quality of their lives by using assistive technology.

Postsecondary Students with Disabilities

Postsecondary education (i.e., obtaining a degree from a college, university, 2-year community college, or vocational school) increases the probability of a person obtaining employment and enhancing one's quality of life. The employment rate for people with a disability increases by about 20 % when they obtain a postsecondary degree (Yelin and Katz 1994). About 9–17 % of college students in the United States have a reported disability, with the most common being a learning disability (LD) (e.g., dyslexia) (Quinlan et al. 2012; Rothstein 2006). Students with physical, visual, hearing, learning, and/or developmental disabilities often require supports and services beyond those typically provided to students without disability because they face additional challenges in meeting the demands of postsecondary education (Gobbo and Shmulsky 2012; Hutcheon and Wolbring 2012; Moh 2012;

White et al. 2011). While all students have access to the increasing availability of technology, those with disability often need assistive technology supports to augment or enable their functional capabilities so that they can access the same materials and environments as students without disability.

Given that technology is ubiquitous in the western culture, postsecondary students have access to a wide variety of technological supports. Many of these supports are available to all students, but some are specific to content areas that students with disabilities find particularly challenging due to the nature of their disabilities (e.g., learning, vision, speech). Thus, students with learning disabilities who have problems with writing and spelling may use software for spelling and grammar check, abbreviations, word prediction, voice recognition, and digital recording. Those who have problems in reading may use screen reader software, large screen computer monitors, screen magnification software, talking dictionaries, optical character recognition systems, audio texts, and reading pens. Those facing challenges in mathematics and science may use modified laboratory equipment, mathematical symbol speech recognition software, and talking calculators and those with speech problems may use speech-generating devices (SGDs). For those with organization and self-management challenges, there are digital calendars and day planners, concept mapping and/or outlining software, noise blocking headsets, and online scheduling and planning websites.

In Chap. 3, Lang and colleagues review the use of these assistive technologies to support and empower postsecondary students with disabilities. In particular, they review three areas of research related to assistive technology for postsecondary students including research aimed at identifying the types of assistive technology options available, intervention studies designed to evaluate the potential benefits of assistive technology, and obstacles to the provision or continued use of assistive technology. They also discuss the wide array of available assistive technology options for students with various disabilities.

Communication Disorders

Communication disorders are generally understood to involve impairment with respect to the sending and/or receiving of messages that result from such conditions as aphasia, autism, cerebral palsy, dysarthria, intellectual disability, and severe/multiple disabilities. The nature and severity of the communication disorder may vary across individuals with the same condition, and may arise in relation to voice, speech, language, and hearing problems. In Chap. 4, Sigafoos and colleagues review research that has evaluated the use of assistive communication technologies to improve message exchange by people with specific types of communication disorders, with a particular focus on sending messages. The studies are divided into three groups, based on the nature of the presenting communication disorder, including people with cerebral palsy, other motor speech disorders (e.g., apraxia, dysarthria, and amyotrophic lateral sclerosis), and aphasia.

Some individuals with cerebral palsy have impaired speech and language development, which may range from mild to severe articulation and fluency problems to significantly delayed language development to the complete absence of functional spoken language (Schlosser et al. 2007). Assistive technology can be used to enable these individuals to have more intelligible speech or functional communication through nonspeech modalities. SGDs are the most commonly used assistive technology in this population. For example, to teach a person to make a request, photographic symbols of preferred items can be attached to an SGD, which is then programmed so that a touch on the chosen photograph produces the corresponding request as a speech output (Schepis et al. 1996). SGDs can be used to increase communication between a child with cerebral palsy and severe communication impairment and a peer without any communication impairment. In such cases, the child with communication impairment uses the SGD to respond to questions posed by the nondisabled peer (Clarke and Wilkinson 2007). In other cases, assistive technologies can be custom made to match the physical and cognitive capacity of the individuals (e.g., Hreha and Snowdon 2011).

Assistive technologies have been used to enhance communication by individuals with motor control impairments who have speech and communication disorders. For example, assistive communication technology can help individuals with severe apraxia and developmental apraxia of speech to supplement natural speech, thereby enabling more effective communication (Cumley and Swanson 1999). It is also used with people with severe dysarthria—the disruption of muscular control that affects speech intelligibility—whose speech may be unintelligible to unfamiliar listeners (Parker et al. 2006). The assistive communication technology used in such cases enables the person to produce digitized or synthetic speech output that is more intelligible than his or her natural speech. Recently, assistive technology has been used with people who have amyotrophic lateral sclerosis (ALS), a condition characterized by muscle atrophy, spasticity, and breathing problems (Ahmed and Wicklund 2011). People with ALS often lose motor ability that is required for speech (i.e., anarthria) and this loss is progressive, resulting in worsening motor movements over time. Thus, customized assistive technologies to enhance communication in this population may be needed, such as eye gaze communication boards, and computer and software accessed via an optic microswitch activated by minimal movements of the person (Lancioni et al. 2012a).

Finally, assistive communication technology has been used with people who have aphasia, a condition characterized by impairment in the expression of speech and the understanding of language. Aphasia typically results from damage to language centers of the brain due to stroke, head injury, brain tumor, infection, or dementia (Schlosser et al. 2007). People with aphasia may also exhibit impairments in reading and writing. A number of assistive technology devices have been used with this population, including voice recognition software (Bruce et al. 2003), and computer-based speaking and writing programs (Behrns et al. 2009; Jokel et al. 2009; Linebarger et al. 2007; van de Standt-Koenderman et al. 2007). These studies attest to the utility of assistive technologies in enhancing communication in people with communication disorders.

Visual Impairments and Blindness

According to the 2004 World Health Report, about 272.4 million people were estimated to have visual impairments (defined as visual acuity of <6/18 to 3/60 in the better seeing eye) and 42.7 million had blindness (defined as visual acuity of <3/60 in the better eye) (World Health Organization 2004). The overall prevalence of visual impairments and blindness in the United States is unavailable because no comprehensive registry exists, and current prevalence studies have used different definitions, age ranges, and geographical locations. However, what is indisputable is that both conditions may be detrimental to the physical, cognitive, linguistic, social, and academic development of children, and may give rise to problem behaviors (Bergwerk 2011; Brodsky 2010; Houwen et al. 2010). The impact of these conditions is often moderated by a variety of physical, medical, social, and behavioral factors (Davidson and Quinn 2011) and potentially by the provision of supports, such as assistive technology.

In Chap. 5, Mulloy and colleagues focus on assistive technology for students with visual impairments and blindness to increase or improve their functional capabilities, support their education and development, and facilitate their independence (Desch 2013). The process begins with an assessment of the students' skills and abilities, functional limitations, and learning needs, as well as task analyses of activities for which they will receive support. This information is then used to select or develop assistive technology devices that best fit the students' needs and improve the quality of their lives. This chapter presents a review of assistive technologies used with children for pre-academic learning, reading, writing, mathematics, and science. The assistive technologies have been designed to either enhance the sight capabilities of the children or engage senses and abilities other than sight.

A number of assistive technologies have been developed to enhance sight capabilities of children, including toys and adapted play areas, facial treatments, and electronic vision enhancement systems (also known as closed-circuit televisions) (Hyvarinen 2000). In addition, assistive technologies have been developed that engage children's senses and abilities other than sight (Holbrook 2006), including textured toys and Braille readiness books (Roth and Fee 2011). Assistive technologies have been developed for specific academic content areas as well. For example, the following are typically used for reading: large print text (i.e., font sizes 18 or greater) (Kitchel 2013), typoscopes (i.e., non-optical devices overlaid on print matter) which reduce glare and support the child's scanning across a page (Lueck and Heinze 2004), reading stands (Presley and D'Andrea 2009), lamps (Bowers et al. 2001), lens-based magnification aids (Bowers et al. 2001), electronic magnification aids (Wolffsohn and Peterson 2003), Braille reading materials (Ryles 1997), audio format materials (Adetoro 2012), and screen and document reading software (Lazar et al. 2007).

Various assistive technologies have been developed to support students with visual impairments and blindness including paper and writing utensils that provide visual and tactile cues (Ponchillia and Ponchillia 1996), typoscopes that help guide letter formation, spacing, and placement via provision of physical boundaries and contrast; Braille making devices (Koenig and Holbrook 2000), voice recorders for note taking (Beech 2010), speech-to-text software (Nicohls 2013), text-to-speech software (Nicohls 2013), and spelling and grammar checking software (Evans et al. 2003). Assistive technologies for mathematics include interactive whiteboards (Bosetti et al. 2011), adapted graph paper (Landau et al. 2003), adapted calculators (Bouck et al. 2011), abacus (Ferrell 2006), math manipulatives (La Voy 2009), tactile graphics (Jayant 2006), and Braille translation software for mathematics (Cooper 2007). Finally, there are assistive technologies for science, including three-dimensional models (Jones et al. 2006), tactile graphics (Jayant 2006), data collection aids (LiveScience 2013), and personalized computer-based laboratory equipment. All of these approaches suggest that assistive technology is well ensconced in the lives of our children with visual impairments and blindness.

Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) is a group of neurodevelopment disorders that include autistic disorder, Asperger disorder, and pervasive developmental disorder not otherwise specified (American Psychiatric Association 2000). People with ASD display mild to severe impairments in social interaction and communication along with restricted, repetitive, and ritualized patterns of behaviors, interests, and activities. Its prevalence is increasing and current estimates indicate that about 2 % of children aged 6–17 years have diagnosed ASD (Blumberg et al. 2013).

Assistive technology is increasingly used with individuals with ASD due to obstacles arising from their symptoms and the learning and behavioral characteristics associated with ASD (Francis et al. 2009; Mechling 2011; Shane et al. 2012). In Chap. 6, Lang and colleagues provide a review and discussion of assistive technology that supports or improves communication skills, social and emotional skills, and daily living and other adaptive skills of people with ASD. In each of these areas, they summarize the research in terms of participant characteristics, dependent variables, intervention components, and outcomes.

There is wide variation in communication skills of people with ASD, ranging from those with reasonably good speech skills to those who fail to develop any speech at all (Howlin 2003; Weitz et al. 1997). Even those with good speech skills may still struggle with social discourse due to perseveration on specific topics, echolalia, idiosyncratic reactions to social cues from conversation partners, or anxiety related to social situations (Scheuermann and Webber 2002; Sigafoos et al. 2007). Augmentative and alternative communication systems (AAC) have been used to support communication in people with ASD. These systems include low-tech (e.g., communication boards) and high-tech (e.g., speech-generating devices) devices that generally include visual cues (Shane et al. 2012). The best fit of an

AAC modality for a specific individual will depend on the physical impairments and cognitive capacity of that individual (Sigafoos and Drasgow 2001).

People with ASD typically exhibit deficits in emotional reciprocity and social relationships (Rao et al. 2008; White et al. 2007). These deficits leave people with ASD vulnerable to social isolation, bullying, and academic and vocational underachievement (Lang et al. 2010). Research suggests instructional assistive technology can be used to compensate or overcome these deficits in people with ASD (Rao et al. 2008; Reed et al. 2011; Shukla-Mehta et al. 2010). As noted by Lang and colleagues in Chap. 6, assistive technology has been successfully used to: (a) initiate conversations, (b) engage in more sophisticated and social forms of play, (c) utilize social conventions and norms during conversations, (d) respond to the social initiations of others, (e) solve social problems, and (f) identify and regulate emotions and emotional reciprocity.

To function independently in the community, people with ASD need to have adaptive and daily living skills, such as self-care, time and money management, and community and recreational skills. Having these skills promotes self-determination and enhanced quality of life. People with ASD, however, often struggle to acquire these skills, and have to rely on their caregivers for assistance (Smith et al. 2012). A large number of assistive technology solutions have been reported that can assist these individuals to overcome their deficits in adaptive and daily living skills. For example, instructions delivered using picture-based systems, handheld personal computers, auditory prompting systems, and video models have been found effective in enabling people with ASD to prepare their own meals (Mechling 2008), video-taped instructional models and slide show examples have been effective in teaching grocery shopping skills (Morse et al. 1996), and various low- and high-tech instructional modalities have been effective in teaching domestic skills (Palmen et al. 2012).

Behavior Problems

In Chap. 7, O'Reilly and colleagues broadly conceptualize problem behaviors as those that (a) are harmful to the person's health and safety or to the health and safety of others sharing the person's environment and/or (b) can interfere with the person's access to age-appropriate regular community settings. The topographies of such behavior vary, but generally include aggression to others, self-injury, stereotypy, and property destruction (Emerson and Einfeld 2011). These behaviors are most often evidenced in individuals with emotional and behavioral disorders (EBD), attention deficit hyperactivity disorder (ADHD), ASD, and intellectual/multiple disabilities (ID) (Vaughn et al. 2011).

While there are a few studies that have assessed the use of technology to reduce behavioral challenges, the main approach has been to increase adaptive behaviors that are incompatible with problem behavior. Two types of assistive technologies have been used: antecedent cue/self-monitoring strategies and consequence-based strategies. Research on antecedent cue/self-monitoring strategies reviewed in this chapter focuses on enhancing stimulus control of adaptive behavior and/or teaching persons to monitor their own behavior. A variety of assistive technologies has been used to promote antecedent cue/self-monitoring, ranging from low-tech (e.g., paper and pencil, timers) approaches (Graham-Day et al. 2010; Legge et al. 2010; Rafferty 2012; Rafferty and Riamondi 2009) to high-tech (e.g., microswitches, computers, iPods, iPads, smartphones) approaches (Blood et al. 2011; Gulchak 2008; Lancioni et al. 2013a; Soares et al. 2009).

Assistive technology has also been used as part of consequence-based strategies to reduce problem behavior. Two general strategies can be identified regarding the way assistive technology has been used for this purpose: (a) to automatically deliver consequences contingent upon problem behavior that subsequently reduces the problem behavior, and (b) as part of augmentative communication interventions to enhance overall communication skills. The three most common assistive technologies used include picture exchange communication system (PECS; Lancioni et al. 2007), speech-generating devices (SGDs; Mirenda and Iacono 2009), and microswitches (Lancioni et al. 2005).

In general, assistive technology appears to be a viable intervention for reducing or eliminating problem behavior, either through antecedent or consequent strategies. Research evidence indicates that assistive technology can be used to successfully reduce problem behaviors that range from off-task during academic instruction sessions to dangerous forms of self-injury, such as head hitting. It has been successfully used in a variety of contexts, including classrooms, adult day centers, and community settings such as grocery stores. Furthermore, it has been used across diagnostic groups (such as EBD, ADHD, ASD, and ID) and ages (from 3 to 51 years).

Alzheimer’s Disease

Alzheimer’s disease, the most common neurodegenerative disease in the industrialized world, is characterized by a slow progressive loss of cognitive functions that ultimately leads to dementia and death. Of the 5.4 million people in the United States that have a current diagnosis of Alzheimer’s disease, 5.2 million are aged $\geq$65 years (Hebert et al. 2003). This means 1 in 8 people aged $\geq$65 years has this disease, and two-thirds of them are women simply because they live longer than men (Fitzpatrick et al. 2004; Hebert et al. 2001; Kukull et al. 2002; Seshadri et al. 1997). Assuming no great medical breakthroughs intervene, when the estimated annual incidence of the disease in the United States doubles by 2050—from one new case every 69 s to one every 33 s (Corrada et al. 2010)—the number of people aged $\geq$65 years with Alzheimer’s disease will increase from 5.2 million to between 11 and 16 million (Hebert et al. 2003).

Alzheimer’s disease manifests in people in different ways and progresses at different rates, but as the disease progresses there is a gradual decline in the person's cognitive and functional abilities. For most people who develop the disease, they are highly frustrated when they become aware of a clear decline in their ability to engage in activities of daily living, such as morning toilet routines, bathing, dressing, and simple cooking (e.g., making a morning cup of tea or coffee, or breakfast). It is at this stage of the development of their disease that assistive technology can be used to either maintain or enhance the quality of their lives. Assistive technology may be of limited value to them with further progression of the disease when they increasingly lose their ability to communicate, move around, and recognize close family members.

In Chap. 8, Singh and colleagues review the literature on assistive technologies that have been used to maximize the residual abilities of individuals with Alzheimer's disease. While assistive technology has been used fairly extensively with people that have general cognitive disorders, its application specifically to individuals with Alzheimer's disease has been rather limited (LoPresti et al. 2004). This situation developed because it was thought that assistive technologies would not be applicable or effective enough to overcome the ravages of this progressive neurodegenerative disease. The enduring question was whether the change produced through the use of assistive technology would be meaningful in the lives of people with this disease. Chapter 8 asserts that technology has been increasingly used to enhance functioning by giving people with the disease supportive tools that they can use to manipulate their environment in a planned and meaningful manner.

Various levels of technology have been used to assist people with the disease to improve the quality of their lives. For example, technology-supported verbal instructions and pictorial cues have been used to enable them to perform activities of daily living (Lancioni et al. 2009, 2012b). Individuals who participated in these studies learned to use such technology fairly easily and rapidly, and maintained the learning over short periods. A series of studies on technology-supported self-regulation of music indicate that people with Alzheimer's disease can reengage in leisure skills, even at the severe stage of their illness (e.g., Lancioni et al. 2013b). The series of studies on indoor travel indicate that technology-aided travel results in secondary benefits, such as social interaction with others and employment (e.g., delivering internal mail) (e.g., Lancioni et al. 2011, 2013c). There is preliminary evidence supporting the use of computer-aided telephone systems by people with the disease to maintain contact with family and friends, thus increasing their social connectedness (e.g., Perilli et al. 2012, 2013). There is some research on using assistive technology for wayfinding, wandering, and personal hygiene specifically with people with Alzheimer's disease. Finally, there is some innovative research on communication systems for people with the disease, such as the use of memory wallets, personalized reminiscences, smart phones to periodically collect autobiographical data that can later be used in conversations, and computer-based multimedia systems.

Learning Disabilities

According to the U.S. Department of Education (2002), about 6 % of school age children and about half of students with disabilities have a learning disability (LD). The various definitions of LD suggest it is a neurological condition that interferes with an individual's ability to store, process, or produce information, and thus affects reading, writing, mathematics, listening, speaking, and reasoning abilities. Other deficits may include attention, memory, coordination, social skills, and emotional maturity. Not all students with LD have disabilities in all areas, but many have multiple LDs. Assistive technology can be used to help students with their LD, especially in reading, writing, and mathematics.

In Chap. 9, Bryant and colleagues review the literature on the use of assistive technologies in learning disabilities within the Adaptations Framework (Bryant and Bryant 1998), which enables students with LD to access the general education curriculum (Bryant et al. 2008). In this framework, a device is termed assistive technology when it is used to maintain or improve the functional capabilities of students with disabilities. The match between a student with LD and an assistive technology device begins with a multidimensional assessment that includes an analysis of the relationship among (a) the student's specific strengths, weaknesses, prior experiences, knowledge, and interests; (b) specific tasks to be performed, such as reading; (c) specific contexts of interaction (across content areas); and (d) specific device qualities (Bryant and Bryant 2011). This assessment enables teachers to find the assistive technology device that best suits a given student.

Several assistive technology devices have been used with students with LD. For example, computer-assisted instruction (CAI) has been used as a mechanism for instruction in reading, writing, and mathematics. It is important that instructional design variables are considered when using CAI with students with LD. In Chap. 9, for example, Bryant and colleagues list the following as critical variables for teachers to consider: (a) providing feedback and error correction opportunities; (b) ensuring multiple practice/examples and appropriate review opportunities (e.g., pre-requisite skills, cumulative review, technology training); (c) including empirically-validated instructional strategies or principles (e.g., explicit, systematic instruction); (d) providing systematic curriculum organized with logically sequenced skills; (e) allowing for adjustable individual preferences (e.g., pace, level, time, goal); (f) recording students data and providing progress monitoring; (g) enhancing motivation, and (h) providing contents in multiple formats (e.g., text, graphics, spoken words). CAI has traditionally been used with desktop or laptop computers, but as technology has developed it can now be used on mobile devices, such as smartphones and iPads (Nirvi 2011).

Other assistive technologies have also been used with students with LD. For example, word prediction and text-to-speech technologies have been used to improve writing performance (Silió and Barbetta 2010), spell checkers to reduce spelling errors (MacArthur et al. 1996), iPads to teach multiplication facts and the Math Explorer program to teach problem-solving skills (Seo and Bryant 2012).

The research presented in this chapter attests to the effectiveness of using assistive technologies to enhance the reading, writing, and mathematics performance of students with LDs.

Severe/Profound Intellectual and Multiple Disabilities

About 2–3 % of the population has an intellectual disability, which is defined as an IQ below 70 and deficits in adaptive behavior or daily living skills. Those with an IQ between 20 and 35 are classified as functioning at the severe level and those with an IQ of less than 20 are classified as functioning at the profound level. People who function at the severe and profound levels of intellectual disability, and have other disabilities (such as medical, physical, behavioral issues), often need assistance in personal care and daily living skills, communication, occupational skills, ambulation, and accessing services. For these individuals, assistive technology can improve the quality of their lives by enhancing their adaptive behavior, environmental stimulation, communication, ambulation skills, indoor orientation and travel, and task engagement.

In Chap. 10, Lancioni and colleagues review studies that used technology to enable people with severe/profound intellectual and multiple disabilities to improve the quality of their lives. The studies are divided into four groups based on the type of technology they assessed: microswitches, SGDs, spatial orientation systems, or activity instruction systems. In general, microswitches enable people to gain control over environmental stimuli even when they may not possess the motor skills necessary to manipulate the sources of such stimuli (Holburn et al. 2004). For example, an optic microswitch attached to the person's wheelchair tray enables the person to activate brief periods of preferred stimulation with a simple hand movement (Lancioni et al. 2001). A pressure microswitch arranged on the headrest of the person's wheelchair enables the person to activate brief periods of vibratory stimulation or music with a simple head movement (Lancioni et al. 2002). A review of this literature suggests that microswitches are very helpful for (a) promoting adaptive responding and positive occupation, (b) combining adaptive responding and occupation with the reduction of problem postures and behavior, and (c) enhancing basic levels of ambulation by individuals with severe/profound and multiple disabilities (Lancioni et al. 2013a). In addition, there is ample evidence that the use of microswitches increases the individuals' indices of happiness, which is often viewed as an index of improved quality of life (Dillon and Carr 2007; Szymanski 2000).

SGDs, also known as voice-output communication aids (VOCAs), are a form of assistive technology that allows a person without functional speech abilities to formulate verbal communication messages through nonverbal responses. People who may benefit most from this technology are those who (a) can only produce unintelligible speech, (b) have lost the ability to speak, or (c) have failed to develop any or sufficient speech abilities (Hemsley et al. 2001; Sigafoos et al. 2009).

Effective use of SGDs depends on how well the technology matches the characteristics of the individual with severe/profound and multiple disabilities and the suitability of the intervention procedures for teaching the individual to use it. Typically, these individuals use SGDs to get the attention of caregivers, and to request items and activities that they may want but are unable to reach independently (Lancioni et al. 2013a).

People with intellectual and multiple disabilities, as well as those with neurodegenerative diseases (e.g., Alzheimer's disease), often have orientation and mobility problems (Gadler et al. 2009; Marquardt and Schmieg 2009). Such problems may prevent these individuals from engaging in independent activities, confine them to specific locations, diminish their self-assurance, and depress their developmental and social opportunities (Karvonen et al. 2004; Provencher et al. 2008). This chapter reviews two broad categories of technology-assisted strategies—orientation systems based on direction cues and orientation systems based on corrective feedback—that have helped people with orientation and mobility problems (Cherrier et al. 2001; Lancioni et al. 2013a; Martinsen et al. 2007).

People with severe/profound and multiple disabilities often face difficulties in undertaking functional activities because of cognitive or motivational limitations. However, engaging in functional activities would be beneficial for them in terms of increasing general stimulation, reducing negative incompatible behavior, and improving social status. This chapter reviews the extant literature on the use of assistive technology for increasing functional activities. The focus is on two main types of technologies: the use of pictorial instructions presented through computer-aided packages requiring a simplified response to request the next instruction, and video prompts that present dynamic visual instructions (Banda et al. 2011; Bidwell and Rehfeldt 2004). Lancioni and colleagues review a large number of assistive technology solutions for individuals who suffer from severe/profound and multiple disabilities.

In sum, the aim of this book is to assist support staff and caregivers in their efforts to make effective use of assistive technology for a range of people in their care. It also provides practical information for people with various disabilities so that they can themselves enhance the quality of their lives. In addition, it provides practitioners and researchers a rich source of current information that may spur them to push the boundaries of assistive technology and continue to improve the quality of lives of people with diverse abilities.

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Chapter 2
Assistive Technology for People with Acquired Brain Injury

Mandy Rispoli, Wendy Machalicek and Russell Lang

Introduction

Acquired brain injury (ABI) is the leading cause of death and disability worldwide (U.S. Department of Health and Human Services, National Institutes of Health [NIH] 2013). It has been reported that over 10 million people incur an ABI yearly across the globe (Bragge et al. 2012) and can cost the United States up to $60 billion annually (Finkelstein et al. 2006). According to the NIH (2013), there are over 5 million people living with ABI in the United States today who require continuous support and assistance in completing daily tasks, particularly in the areas of cognition, physical mobility, adaptive behaviors, and engagement in socially appropriate behavior (Flanagan et al. 2008). These deficits can negatively impact the individual's social relationships, educational gains, employability, and community life (Ross et al. 2011).

ABI refers to damage to the brain after birth resulting in impairments in typical functioning (Fletcher et al. 1990). Causes of ABI can include infection, substance abuse, or loss of oxygen to the brain, as in the case of a stroke (US Department of Health and Human Services, Center for Disease Control [CDC] 2010). Traumatic brain injury (TBI) is the most common cause of acquired brain injury. TBI refers to an external injury to the brain and can be classified into two subgroups: closed head injury and penetrating head injury. A closed head injury occurs when an object suddenly and forcefully comes into contact with the

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individual's head. A penetrating head injury occurs when an object enters the individual's brain tissue. TBI is most often a result of falls, motor vehicle accidents, being struck by an object, sports accidents, or physical assaults. According to the NIH (2013), individuals between the ages of 15 and 24 years, those over 75 years, and those younger than 5 years are at the highest risk of sustaining a TBI.

The second major cause of ABI results from internal injury to the brain. A cerebrovascular accident (CVA), or stroke, is the most common type of internal brain injury in which blood supply to the brain is disrupted. This loss of access to blood can cause brain cells to die, leading to brain injury. Because CVA can impact a variety of areas of the brain, the resulting damage and deficits vary across individuals. Unlike TBI, which tends to have the highest incidence in people between the ages of 15 and 24, CVA is most likely to affect individuals over the age of 65 years (U.S. Department of Health and Human Services [CDC] 2012). While anyone is vulnerable to having a CVA, additional risk factors include poor diet, smoking, lack of exercise, excessive consumption of alcohol, and hypertension (CDC 2012).

Effects of Acquired Brain Injury

ABI can be classified as mild, moderate, or severe. Mild ABI is associated with a loss of consciousness for less than 30 min and temporary post-traumatic amnesia, in which the individual has difficulty recalling events surrounding the incident in which the damage was incurred. Moderate ABI is often caused by loss of consciousness for more than 30 min, but less than 24 h, and post-traumatic amnesia that persists for more than 24 h. Severe brain injury consists of loss of consciousness for over 24 h and post-traumatic amnesia persisting for 7 days or longer (Corrigan et al. 2010).

The impact of ABI on the individual's functioning can be temporary or permanent. For those individuals who sustain moderate to severe ABI, many may never fully recover and often require continued support (Maas et al. 2008). ABI may result in changes in personality as well as loss of cognitive skills such as memory or decision making, loss of communication skills, decreased mobility, loss of adaptive and leisure skills, and vocational skills (U.S. Department of Health and Human Services [NIH] 1999). In order to address these specific deficits and needs, effective rehabilitation treatments are needed throughout the lifespan.

Recovery and Treatment

Treatment goals for persons with ABI may be restorative in nature; that is, the goal may be to restore or improve the individual's functioning. For example, participating in a virtual reality simulation may facilitate the re-emergence of a previously mastered behavior. An individual who was able to drive a car independently prior to sustaining an ABI may be able to regain that skill by learning to drive using a virtual reality program. Other goals may be compensatory in nature by assisting the person in adapting to their skill loss in order to interact with the environment. For example, an individual who has lost the ability to speak may make use of a speech-generating device in order to communicate their needs and wants. In some cases, compensatory goals may also produce restorative benefits. For example, an individual whose memory has been compromised due to ABI may have a compensatory goal of using an electronic device to remind him or her of appointments or tasks. The frequent use of this compensatory device may result in improved memory (de Joode et al. 2010). All of these examples illustrate the use of assistive technology (AT) in both restorative and compensatory treatment for persons with ABI.

The developmental and refinement of assistive technologies has greatly improved treatment outcomes for individuals with ABI (Wallace and Bradshaw 2011). AT provides a means by which individuals with ABI can regain some of the independence, self-determination, and autonomy that was lost due to their brain injury (Dry et al. 2006). AT is defined as any item or equipment that is used to improve or maintain an individual's independence and/or functioning (Assistive Technology Act of 1998, 2004).

AT may range in complexity from low-tech to hi-tech. Low-tech AT refers to items or equipment that are readily available to those with and without disabilities, such as a pocket calendar intended to assist in planning and remembering tasks and activities. Low-tech AT is a frequently used, effective, and low cost option for supporting individuals with ABI across a range of skill domains (Evans et al. 2003). Hi-tech AT may include, but are not limited to, portable electronic devices to assist in memory (Sohlberg et al. 2007b), microswitches to allow the individual to interact with their environment (Lancioni et al. 2011d), or speech-generating devices to provide opportunities for communication and social interaction (Johnson et al. 2008).

The purpose of this chapter is to provide a review of the research supporting the use of low-tech and hi-tech AT with persons who have ABI as well as clinical and academic implications. The chapter is organized into skill domain areas in which AT has been applied to assist in the rehabilitation of persons with ABI. These skill domains include: (a) cognition, (b) communication, (c) leisure skills, and (d) vocational skills.

Cognition

ABI can have acute and lasting effects on cognitive functioning and may result in lifelong disability (Bergquist et al. 2009). One of the primary cognitive areas impacted by ABI is memory and executive functioning (Dry et al. 2006). Though the severity of memory and executive functioning deficits varies across individuals with ABI, most experience some level of difficulty in storing and retrieving relevant information about themselves, other people, and events. Individuals with ABI may have difficulty completing simple tasks, such as remembering to take medication (Wilson et al. 2001), as well as more complex, organizational tasks such as scheduling and keeping appointments and recalling relevant information needed to complete tasks at home or at work (de Joode et al. 2010). Such cognitive deficits can further impact an individual's daily life by creating dependence on others for organizing and managing daily tasks and activities (De Pompei et al. 2008).

Research has yet to identify a treatment with restorative benefits for cognitive skills in persons with ABI. For this reason, most cognitive treatments are compensatory. The use of AT to compensate for memory and executive functioning deficits is considered to be the most effective treatment for memory impairments in persons with ABI (Sohlberg et al. 2007b). AT can be used to reduce the difficulty level of a given task or to reduce an individual's need to rely on cognitive skills in order to complete a task. For example, Van Hulle and Hux (2006) taught three individuals with TBI to wear a wristwatch with an alarm to remind them to take medication so that they did not have to rely on memory. Results of the study showed that two of the three participants made substantial gains in taking medication without the need for support staff reminders.

Although AT exist to improve functioning for individuals with ABI, there are numerous barriers to the use of AT by consumers (Gartland 2004; Lemoncello et al. 2011). Research indicates that few people are using electronic memory aids and instead rely on low-tech memory aids (Evans et al. 2003). The most commonly used types of external aid to cognition for persons with ABI are low-tech paper-based products such as calendars, "to do" lists, sticky notes and daily planners (De Pompei et al. 2008), or memory notebooks. Memory notebooks typically consist of daily planners and calendars, such as a weekly calendar, a "to-do" list, and a section to record the events of the day (McKerracher et al. 2005) (Fig. 2.1).

McKerracher et al. (2005) compared two memory notebook formats with a 46-year-old man with TBI. The first memory notebook was described as "standard" and contained two sections, a weekly calendar and a weekly to-do list, separated by a plastic divider. The second notebook was modified in that a daily schedule and a daily to-do list were placed on adjacent pages. The participant was taught to use each diary via systematic verbal prompting and feedback. Training was provided during the last 10 min of his scheduled rehabilitation sessions. Data were collected on the participant's performance on five tasks that involved memory, such as telephoning his case manager and bringing paperwork to his therapy appointments. Results showed that use of the modified memory notebook was associated with a higher number of tasks completed independently for the week than the standard memory notebook. These findings suggest that tailoring the design of memory

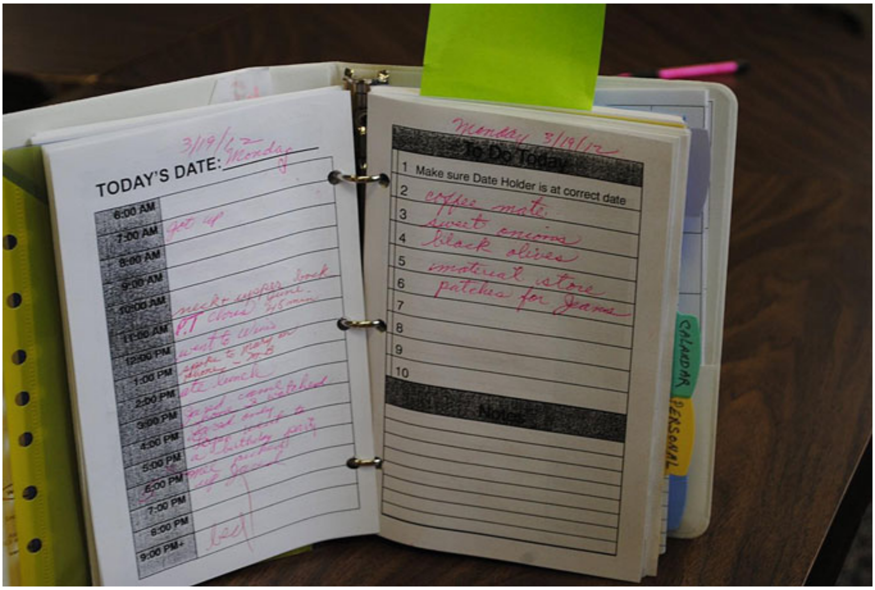

Fig. 2.1 Low-tech memory notebook. A low-tech memory notebook allows users to record appointments, create "to-do" lists, and record notes from the day. Retrieved from http://news.wsu.edu/Pages/Publications.asp?Action=Detail&PublicationID=30980

notebooks to patient characteristics and preferences may be beneficial in producing positive outcomes.

Sandler and Harris (1992) present a case study of a young adult male who sustained TBI at 18-years old and had significant memory deficits as a result. The patient lived in a long-term residential treatment facility for persons with TBI. The purpose of the case study was to evaluate the patient's use of a memory notebook. The memory notebook consisted of a file folder, which contained a monthly calendar, a schedule of group meetings, and weekly therapy appointments. The researchers reported that during the first 3 months after the patient was provided the memory notebook, the patient misplaced the notebook regularly and did not bring it to therapy sessions or take it with him following the conclusion of the therapy session.

The staff made modifications to the memory notebook including (a) using a large three ring binder rather than a file folder to help differentiate it from other stimuli in the patient's environment, and (b) adding a daily schedule to the notebook each morning. Instructional modifications were also made to enhance the patient's use of the notebook. Prior to each therapy session or group meeting, the staff verbally prompted the patient to return to his room to retrieve the notebook. In addition, a visual task analysis was posted on the patient's bathroom door prompting him to get the notebook, open to the calendar, and complete steps involved in determining the current day and appointments.

Ten months after these modifications were put in place, the authors reported the patient's use of the memory notebook improved and that he consistently brought the memory notebook with him to all appointments without verbal prompts. Though this is a case study, and experimental control was not demonstrated, the report does suggest that perhaps simply presenting individuals with a memory notebook may not be sufficient in improving outcomes without explicit instructions and other environmental cues.

In recent years, the use of hi-tech devices and technology has been the focus of research on AT to address cognitive needs of persons with ABI. Some drawbacks of hi- tech AT include the need for the patient to learn to use the device, which may require the use of cognitive skills, and the social stigma that may arise from interacting with the AT device or software (Wade and Troy 2001). However, the increased popularity, portability, and acceptability of technology in the daily lives of individuals without disabilities may help ameliorate the social stigmatization of reliance on AT. In contrast to low-tech AT, hi-tech AT provides "active reminders" to users by alerting them to the device or to the task to be completed (McDonald et al. 2011). Hi-tech AT for persons with ABI may include electronic devices that are widely used by individuals without brain injury such as pagers, cell phones, PDAs, electronic diaries, instant messaging programs, and Internet calendars (Bergquist et al. 2009; McDonald et al. 2011).

Electronic memory aids. Electronic memory aids have been used to support individuals with ABI in their daily lives by assisting them with driving (Anshutz et al. 2010; Klarborg et al. 2012; Lane and Benoitb 2011), dealing with getting lost (Lemoncello et al. 2010; Sohlberg et al. 2007b) and cooking (Zhang et al. 2001). Electronic memory aids may be used to assist individuals with tasks requiring higher-level cognitive skills, such as budgeting (Bergman 2002) and planning out daily routines (Boman et al. 2007; Fish et al. 2008; Gorman et al. 2003).

Boman et al. (2007) equipped two apartments with electronic aids for daily living (EADL) to assess if eight adult participants with moderate ABI would be able to utilize the AT to improve their ability to perform daily tasks (e.g., planning and preparing meals, remembering to lock doors, engaging in recreation and leisure activities). The EADL included AT such as (a) a stove guard that shuts off power when something is burning, (b) an alarm to signal that the refrigerator door has been left open or that there is a leak, and (c) a remote control placed next to each participant's bed that will turn of all lighting, power to stove, and will alert the participant if the front door is unlocked. Results showed that it took participants a median of 4 weeks to learn how to use these EADL with a range from 2 to 24 weeks. Most participants also rated themselves as having less difficulty engaging in daily living activities as a result of the EADL. Despite these promising results, research in the use of AT embedded into home environments is an emerging area where continued research is needed.

Handheld electronic devices. Smartphones, and other handheld electronic devices such as pagers, personal data assistants (PDAs), electronic diaries, and pocket computers may be used to compensate for cognitive impairments in persons with ABI. Software that generates reminder messages can be linked to a variety of

Fig. 2.2 Tablet calendar application. The visual schedule planner is an audio-visual tablet application which allows users to create and manage daily, weekly, and monthly schedules. The visual schedule planner is produced by Good Karma Applications, Inc., San Diego, CA

small portable devices in order to cue, or remind the user to complete specific tasks or attend appointments (Thone-Otto and Walther 2003). Such handheld devices can then deliver reminder messages using a variety of outputs such as voicemail, beeps, alarms, text messages, or visual cues. While the portability and lack of social stigma are benefits of handheld electronic devices, practitioners may find it necessary to program the device with a reminder message in the morning to alert the individual to utilize the device during their day (De Pompei et al. 2008) (Fig. 2.2).

Smartphones and cellular phones represent one means of providing individualized support to persons with ABI without drawing attention to their disability. These mobile phones have been shown to assist in compensating for memory impairments by assisting with planning and organization for persons with ABI. Wade and Troy (2001) investigated the effectiveness of cellular phones as AT for persons with memory impairments by providing a specially programmed cellular phone to five individuals with ABI resulting from stroke or TBI. The purpose of the phone was to assist the user to remember to engage in specific daily tasks. Tasks included taking medication, going to lunch groups, taking a walk, preparing a meal, and heading for the bus stop. Each participant's cellular phone was loaded with individualized, pre-recorded messages. Participants were provided with the phones and were given verbal instructions about how to answer the phone to hear the pre-recorded messages. Data were taken on the number of daily tasks the participant completed independently before and after each was provided a cellular phone. Results for all participants showed the use of the cellular phone as a memory aid increased independent engagement in daily tasks.

Similar to smartphones, handheld electronic devices have been used to remind adults and children with ABI to complete daily tasks in rehabilitation and community settings (De Pompei et al. 2008). PDAs and other handheld computers allow the user to receive messages in a variety of settings away from a desktop computer. PDAs have also been used to compensate for cognitive skills required during navigation. For example, Kirsch et al. (2004) taught a 19-year-old male with TBI to use a PDA to help him navigate from one therapy room to another at a rehabilitation treatment facility. The PDA was programed to display a screen with a landmark image in the center and instructional text telling the individual what landmark to attend to and to tap the screen when he arrived at that landmark. The PDA also delivered these written instructions using speech-generating technology. Data were collected on the number of errors made en route during each transition from one therapy room to the next. Results showed that the participant made fewer errors when the PDA delivered navigational cues (e.g., “Turn right here”) compared to when it did not.

Sohlberg et al. (2007a) compared the efficacy of four modes of prompting for route finding provided via a wrist-worn electronic device (i.e., Hewlett-Packard iPaq pocket PC) on the navigation of 20 individuals with severe cognitive disabilities due to ABI. These four types of prompts included (a) aerial map image, (b) point of view map image, (c) text only instructions, and (d) audio only instructions. The effects of the four types of prompts on participant’s pedestrian route finding skills were evaluated. Results showed that participants’ performance was better when provided audio only instructions and they also preferred this type of prompt to the others assessed. These findings suggest that future research should focus on determining the most effective type of prompting to use when using hi-tech devices. Hi-tech devices often enable researchers and clinicians to utilize a number of different types of prompts and some may be more appropriate for some tasks and/or rated as more highly preferred by individuals with ABI.

Internet resources. Online calendar programs have been shown to support the cognitive needs of persons with ABI. Online calendars have the benefit of being accessible on a desktop computer as well as on handheld devices such as tablet computers, PDAs, and smartphones. One online calendar is Google Calendar, a free Internet-based calendar that allows users to schedule one-time and recurring appointments and store relevant information for each appointment, such as location and phone number. Google Calendar can also be synced to smartphones, tablet, and desktop computers in order to allow the user to enter appointments from a variety of locations. Google Calendar will also notify the user, via the synced devices, of upcoming appointments.

McDonald et al. (2011) compared the use of Google Calendar to a standard paper diary on daily memory tasks with 12 adults with ABI. Data were collected on the number of events successfully recalled each week and the percentage of appointments/tasks completed correctly. Results showed that Google Calendar was more effective in improving performance on planning and organizational skills than the paper diary. Nine of the 12 participants indicated they preferred Google Calendar to the standard diary and anticipated continuing to use it. All participants stated they would recommend the Google Calendar to others.

De Joode et al. (2012a) successfully taught 15 adults with ABI to manage daily appointments and events using Microsoft Outlook© 2003. Microsoft Outlook© is another example of an electronic calendar. However, participants with ABI tended to exhibit increased frustration with the software and increased cognitive fatigue as compared to individuals without ABI. As such, for individuals who have difficulty navigating through a standard Internet program, it may be beneficial to explore software and devices designed specifically for persons with ABI.

ABI-specific. Some of the technology frequently used by individuals without disabilities may be too complex for individuals with cognitive impairments resulting from ABI (Sohlberg et al. 2007b). To better fit this population's needs, devices and software specially designed for persons with ABI are available. These devices and software are adapted to meet the needs of persons with ABI by being simple to use and free of distractions. ABI-specific AT may include specialized calendar and diary software, specialized pocket computers, and voice prompting systems (Thone-Otto and Walther 2003; Wright et al. 2001).

One type of ABI-specific memory aid for persons is an alphanumeric pager prompting system in which pagers can be programmed to deliver short text prompts at specific times. The NeuroPage™ (Hersh and Treadgold 1994) is an example of a pager designed for individuals with ABI. NeuroPage is a portable pager that can be attached to a belt and contains a screen and one large button, making it easier to use for persons with motor difficulties. Messages and reminders are entered into a computer, sent to the paging company, and then displayed on the NeuroPage™ at predetermined times.

Fish et al. (2008) compared the effects of a self-monitoring checklist to the use of the NeuroPage™ on task engagement for a woman with ABI. The pager provided 14 daily reminders to engage in specific activities (i.e., orientation/alarm clock, complete morning hygiene and dressing routine, complete activity for the day, meal preparation, take medication, complete evening hygiene and dressing routine). The written self-monitoring checklist aimed to decrease perseverative behavior (i.e., morning routine took 5 h due to compulsive and repetitive behaviors). As she completed each discrete step of her morning routine she was to check off the box next to the step and record the total amount of time her routine took. An alternating treatments design was used to evaluate the two interventions with the final experimental phase consisting of both the pager and checklist.

Results indicated that the pager was associated with shorter tasks duration and higher number of tasks completed (i.e., morning and evening routine and take medication) than the checklist. The results of this study indicate the potential positive outcomes of using a device such as a pager that delivers a tactile prompt followed by a message to change the behavior of individuals with persistent difficulties remembering to engage in daily activities. Additional reminder prompts may be especially useful for individuals who engage in maladaptive behaviors (e.g., obsessive compulsive behaviors) that may prevent them from successfully using memory aids that require them to remember to shift their attention to the cue.

Similar to the alphanumeric pagers, voice prompting systems have also shown benefit to individuals with ABI. Voice prompting systems can record the user's voice and then use the recorded messages to deliver auditory prompts to the users at the necessary times. For example, Hart et al. (2002) taught five adults with ABI to use a voice prompting system in order to record and review their therapy goals. They found that when the participants recorded their goals and then replayed their recording three times daily using the voice prompting system, they were better able to recall and follow through with their goals than those participants in the control group who did not use a voice prompting system. Examples of voice prompting system devices include VoiceCraft™ and Voice Organizer. The VoiceCraft ™ is a handheld alarm that beeps and presents a voice output message to prompt the individual to engage in a specific behavior (Van Hulle and Hux 2006).

The Voice Organizer is a handheld device that can be programed to recognize specific speech patterns and is able to record an individual's voice and then play back those recorded messages at specific times. Van den Broek et al. (2000) evaluated the effects of using the Voice Organizer on completion of daily routines for five adults, ages 25–56 years, with ABI. The effect of the Voice Organizer on completion of daily tasks was compared to use of a paper and pencil to-do list. In the paper and pencil condition, the participants were told they could write down tasks they needed to complete, but they were not to use any other form of memory aid. In the Voice Organizer condition, participants were taught how to record messages and program messages to be played at specific times in order to remind them to complete daily tasks such as vacuuming and cleaning tables. However, the authors did not provide detail on teaching procedures utilized to train participants to use the Voice Organizer. Results suggest that for four of the five participants, performance scores on completion of daily tasks were higher when participants used the Voice Organizer than when participants used paper and pencil to-do lists. Though preliminary, these findings suggest that use of the Voice Organizer may be beneficial for individuals with ABI who have difficulty remembering to complete specific tasks. It is unknown, however, if the Voice Organizer as a product is more beneficial than other handheld voice prompting systems.

Prompting systems may also make use of other technology, such as wristwatches (Van Hulle and Hux 2006) or televisions. The Television Assistance Prompting (TAP) system is a device that contains a small computer that is affixed to a television. The system is designed to provide users with familiar interface and tools (i.e., TV screen and a remote control). The TAP system automatically turns the television on and off in order to deliver messages to the user at pre-specified times using text, visual images, or audio output. These messages are composed using a computer with Internet access and are stored on a secure Internet server (Lemoncello et al. 2011).

Lemoncello et al. (2011) conducted a randomized controlled crossover trial study in order to evaluate the use of the TAP system on the completion of daily cognitive tasks. The authors sought to determine if adults with ABI were able to complete more tasks when the TAP system was installed in their home as compared to their usual memory aids. Twenty-two adults with ABI participated in the study and were randomly assigned to the TAP or control group. Each group experienced both treatment conditions twice by moving to the other condition every 2 weeks. In the control condition, participants were permitted to use the memory supports they typically used, such as adult prompting, calendars, or notes. In the TAP condition, reminders to complete tasks were delivered using the TAP system, which was installed in each participant's home. Care providers were asked not to provide any additional prompts or reinforcement during the 2-week TAP condition.

In each of the two conditions participants were asked to complete six tasks including two preferred tasks, two non-preferred tasks, and two tasks assigned by the researchers. Tasks included such activities as taking medication, completing chores, following up on therapy tasks, going out to eat, and engaging in hobbies. Data were collected on the percentage of tasks independently completed during each condition. Data were also gathered via semi-structured interviews on the participants' satisfaction with the supports provided in each condition. Results for task completion showed that task completion was higher in the TAP condition for both groups than in the control condition with a medium-to-large effect size. Participants reported that the TAP system was easy to use and helpful. The results of this study show that the TAP system is a promising means of incorporating AT into the daily lives of individuals with ABI. However, this is a new technology and replication of these findings is warranted. At the time of the writing of this chapter, the TAP system was not commercially available. Future research is needed to make the TAP system affordable and available to consumers.

Summary. The use of both low-tech and hi-tech AT to compensate for cognitive impairments in individuals with ABI is supported in the literature. Decisions about what type of device to use and whether/how to customize the AT require knowledge of the individual's skills, preferences, and needs. The demands and characteristics of the environment in which the AT is to be used should also be considered. For example, if one is considering a voice prompting system, they will want to consider the noise level of the environment in which the system is to be used to ensure the patient will be able to attend to the prompts. Finally, sustained use of the AT system depends in part on the acceptability, feasibility, and suitability of the AT system to the patient with ABI and his or her support staff (De Pompei et al. 2008).

Communication

The ability to express one's wants, needs, and opinions is an everyday skill that many of us take for granted. For a person who sustains an ABI, this ability to communicate can change suddenly and profoundly. An individual who possesses a functional communication system often has frequent social interactions, has the ability to communicate his or her wants and needs, can voice choices and decisions, and tends to have a greater sense of self-determination than those individuals who lack functional communication (Fox and Sohlberg 2000). Sustaining an ABI can greatly impact this functional communication system.

The change in communication resulting from an ABI varies widely across individuals in terms of severity and duration of impact. Some individuals may have poorly organized speech, making it difficult for a listener to follow the conversation. Others may lose the ability to speak altogether. These communication impairments may be temporary or may persist throughout the persons' life. Common communication impairments following ABI include aphasia (i.e., difficulty speaking or understanding language), apraxia (i.e., poorly coordinated oral motor movements needed to produce clear speech sounds), slow or hesitant speech, deficits in pragmatics (i.e., maintaining a socially appropriate conversation), disorganized speech, or total loss of speech. The impact of the ABI on communication may be exacerbated by cognitive deficits and motor skills resulting from the ABI. These deficits may make it difficult for individuals with ABI to acquire and successfully use new communication strategies (Wallace and Bradshaw 2011).

AT for communication typically involves the use of aided Augmentative and Alternative Communication (AAC; see Chap. 4). Aided AAC involves the use of external materials, such as pictures, electronic devices, books, or boards with text, to assist the person in expressing his or her wants, needs, and opinions. Aided AAC may be used to augment communication by supplementing the individual's existing speech in order to aid clarity and structure. For example, for an individual who has difficulty organizing his speech, a list of key phrases may be written on a card to help cue him to sequence their conversation in a logical manner.

Aided AAC may also be used as an alternative to speech in cases in which speech is no longer present or is minimal or unintelligible (Garrett et al. 1989). Persons with ABI who have total loss of communication may use an alternative communication system in which they point to symbols or pictures representing their wants, needs, and opinions (Johannsen-Horbach et al. 1985). AAC may help compensate for loss of communication skills, thereby allowing the individual to more clearly and effectively communicate. In some cases, the use of AAC has resulted in restorative communication, particularly with young children (Bodine and Beukelman 1991).

AAC has been used to address (a) receptive language skills that involve understanding what is heard or read; (b) expressive language skills, such as labeling, requesting, or commenting; and (c) pragmatic skills needed in social interactions and conversations. Pragmatic skills are one of the hallmark communication impairments of individuals with ABI (Bellon and Rees 2006). For example, persons with ABI may have difficult initiating a conversation, and attending to and adjusting the conversation based on listener cues. These deficits in pragmatics can result in fewer opportunities to interact socially and can lead to social isolation and withdrawal (Bellon and Rees 2006; McDonald 1993).

Low-tech AT is the most common form of AT to address communication deficits in persons with ABI (Fried-Oken et al. 2012). Low-tech AT tends to be inexpensive, easily transportable, and often can be created using readily available materials (Wallace and Bradshaw 2011). Examples of low-tech AT for communication include paper and pencil, written symbols, photographs, letter boards, visual scene displays, and thematic dictionaries (Garrett et al. 1989). Low-tech AT is often used to cue a person to talk about a certain topic, to organize their conversational speech, and to assist in recalling names of specific people or places or details of events. For example, looking at photos from a specific event may assist the person in describing details of the event, including people in attendance or activities that took place (Wallace and Bradshaw 2011). Specific types of low-tech AT for communication include iconic symbols and visual scene displays.

Iconic symbols. Iconic symbols refer to visual representations including pictures, drawings, or symbols of concrete (rather than abstract) nouns, such as people, places, and objects. Research has shown that individuals with ABI are more likely to remember and generalize use of iconic symbols rather than abstract symbols when attempting to communicate (Beck and Fritz 1998). Iconic symbols can be used to facilitate expressive communication by prompting the person to recall and talk about a certain person, place, or event.

These iconic symbols are frequently stored in a communication book. A communication book usually consists of a few pages that have symbols depicting information pertaining to the person with ABI. For example, there might be a page with a photograph of a flower and text at the bottom of the page that reads, "I like to spend time in my garden." Information relating to past or future events as well as hobbies, family, and important people in the individual's life may also be stored in the communication book. In some cases, remnant materials, such as souvenirs or objects like a ticket stub, relating to specific events may be adhered to the book page rather than photographs or drawings. The communication book can be used to prompt the individual to share information with others in conversation. Communication books are typically used with individuals who have difficulty retrieving information when speaking (see Chap. 8) or who have poor receptive language skills (Wallace and Bradshaw 2011).

Ho et al. (2005) examined the effects of a communication book and the stimuli presented within the communication book on social initiation and maintenance of conversations. Two adults with ABI resulting from a stroke (CVA) participated in this study. Both participants had aphasia (i.e., difficulty speaking or understanding language) and had either no verbal communication skills or spoke in fragmented phrases as a result of their ABI. Participants were exposed to three conditions: (a) no communication book, (b) communication book with iconic symbols (computer-generated drawings generated from Boardmaker® software), and (c) communication book with remnants (e.g. maps, photos of family members, tickets). Each page of the communication book contained a simple sentence and a corresponding remnant or image.

Using an ABA design with an embedded alternating treatment design, participants were exposed to the three conditions once daily for 5 days. In each 5-min session, the participant was seated with a conversational partner who was instructed to ask a few open-ended questions to the participant. During the conditions in which the communication book was present, the conversational partner opened the communication book and turned to a page in order to prompt the participant to initiate a comment/conversation. Results showed that both participants initiated more conversations and had fewer communicative breakdowns when the communication book consisting of pictures or consisting of remnant materials were used as compared to when the books were absent. Participants responded more to social initiations during the communication book with remnants condition as compared to the communication book with iconic symbols. There was considerable overlap on social initiation and maintenance of conversation across the communication book with remnants versus with iconic symbols conditions for both participants suggesting that both sets of stimuli may be effective for persons with ABI.

Determining what types of images or pictures to include in a communication book for persons with ABI may present a challenge to clinicians. McKelvey et al. (2010) examined participant preference and accurate use of three types of visual stimuli often included in communication books. These three types of visual stimuli included: (a) personally relevant, contextualized images (photographs in which familiar people, objects, and/or places are depicted within a scene), (b) contextualized images without personally relevant features (commercially available photographs of scenes which include people, objects, or places unfamiliar to the individual), and iconic images (computer-generated drawings generated from Boardmaker® software). Participants included eight adults who had sustained a stroke and who were between the ages of 25–86 years with a mean age of 61 years. The first phase of the study was to assess the participants' preference for each type of visual stimuli. The researcher presented the participants with three images, one from each visual stimulus category, representing a single word. The participants were asked to select the picture they preferred. This procedure was repeated across 45 target words with the position of each visual stimulus counterbalanced across trials. Results showed that for 79 % of trials participants preferred the personally relevant, contextualized stimuli over the contextualized stimuli and the iconic images.

In the second phase of the study, the researchers examined the accuracy with which participants could match a target word to the corresponding image across visual stimuli groups. The researcher verbally stated a target word and asked the participants to identify the corresponding picture out of an array of three pictures, one from each visual stimulus category. Only one picture matched the target word. Results showed that, overall, participants were most accurate when matching words to personally relevant, contextualized photos rather than to iconic images or noncontextualized photos. The findings from this study suggest that individuals with ABI may prefer certain forms of visual representations for communication and that these preferences can be assessed within a trial-based format.

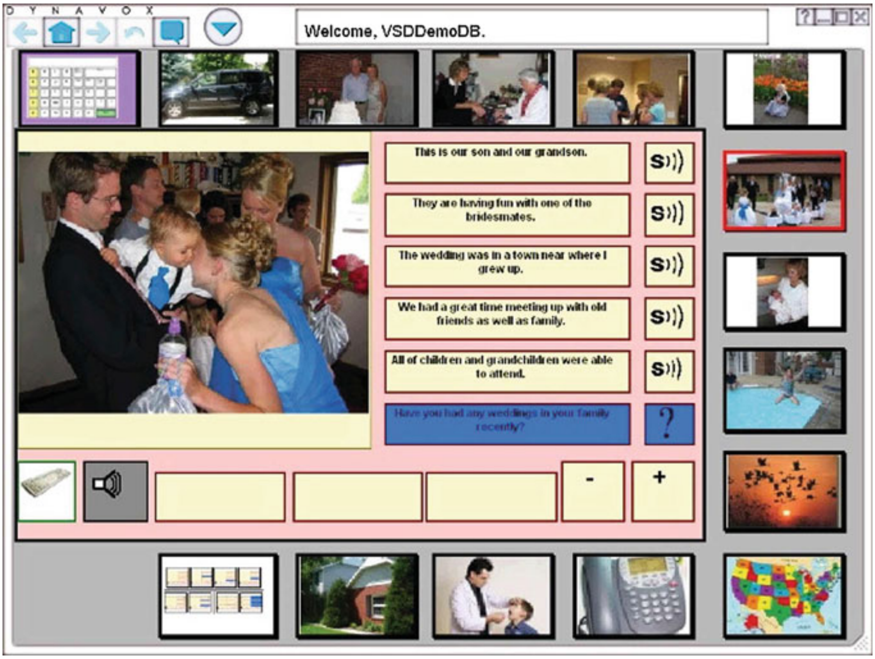

Fig. 2.3 Visual scene display. A hi-tech visual scene display provides contextualized images, written cues along with speech-generating technology to support communication. Adapted from Fried-Oken et al. (2012)

Additionally, the use of personally relevant, contextualized images may promote more accurate communication for individuals with ABI. This finding might be expected given that one of the communication deficits associated with an ABI is difficulty linking abstract images with meaning (Fox et al. 2001). By making these images more concrete and relevant to the individual's life, individuals may be more likely to connect those images with the corresponding words and descriptions and generalize their use to communication exchanges.

Visual scene displays. Similar to personally relevant, contextualized images, visual scene displays place an individual's personal experiences, information, and interests into a concrete format. The goal of a visual scene display is to depict the relationships that exist between the individual and those people and events around him or her (Hux et al. 2010). For example, a visual scene display may include the person's family members gathered around a table eating dinner. At the bottom of the picture, there may be a brief sentence describing the event or the relationship among the people in the photo. Both the individual with ABI and their conversation partner are able to view and refer to the visual scene display in order to co-construct a conversation. Visual scene displays have been used to assist persons with ABI in retrieving and expressing relevant personal information. Visual scene displays can be used with low-tech or with hi-tech AT systems (Fig. 2.3).

Low-tech visual scene displays are typically static photos that can be part of a communication book or a separate document. For example, Hux et al. (2010) taught a 61-year-old male with ABI resulting from CVA to use a low-tech visual scene display. Two pages with visual scene displays were placed in a communication book. One scene depicted a photograph of the participant working on the engine of a classic Chevrolet—a car that was very important to the participant. The second depicted a classic car show. Below each picture were three to five brief phrases relating to the scene depicted on that page. Data were collected on the content and quality of conversations when the visual scene display was (a) present but only viewed by the participant, (b) present and viewed by the participant and the conversation partner, or (c) when the visual scene display was absent. Results showed that when the visual scene display was present and viewable by both the participant and the conversation partner the quality and detail of the content discussed was higher than in the other two conditions. These findings highlight the importance of using a visual scene display as a means for both conversation partners to co-create and guide the conversation.

Although less often used in clinical practice, research has shown hi-tech AT to be an effective means of promoting functional communication in individuals with ABI (Fried-Oken et al. 2012). Hi-tech AT for communication may include speech-generating devices, computer software and interfaces, as well as applications for tablet computers. Hi-tech AT can be similar in many respects to low-tech AT for communication. Many software programs utilize yes/no sections (Doherty et al. 2002), keyboards for spelling out messages (Lancioni et al. 2011a), and visual scene displays (McKelvey et al. 2007).

Speech-generating devices. AT devices may also be used to provide an alternative means for the person with ABI to communicate. Such devices for persons with ABI typically include a speech-generating device (SGD). An SGD is a portable device that produces a pre-recorded (digitized) or synthesized verbal message when activated. Simple SGDs may include a single button, or switch while more complex SGDs can contain dynamic displays that require the user to scan through visual menus in order to select the content of the message they wish to communicate (Wallace et al. 2010). Most SGDs usually involve touch screens that can be activated with hand touch, eye gaze tools, optical head pointers, or joysticks. In some cases, SGDs can be paired with microswitches to enable individuals with limited motor movements to activate the device and communicate their wants and needs (Lancioni et al. 2010a) (Fig. 2.4).

Lancioni et al. (2009b) paired a microswitch with an SGD in order to teach a 35-year-old man with severe TBI and minimally conscious state to request caregiver assistance or attention using an SGD. The participant was seated in a wheel chair and was able to activate the SGD by moving a small device located near his stomach. When activated, the microswitch triggered the SGD to produce a verbal request for a caregiver. The caregiver then responded by providing attention and physical proximity to the participant. Results showed that when use of the SGD led to social interaction with the caregiver, the participant's use of the SGD increased. The results of this preliminary study suggest that individuals with severe ABI may

Fig. 2.4 TouchTalk. The TouchTalk is a lightweight tablet-like speech-generating device with a dynamic display. The TouchTalk is produced by Lingraphica®, Princeton, NJ, USA

be able to initiate social interaction through the use of microswitches paired with SGDs. Research is still needed to determine how these social interactions might be maintained through the use of AT.

Speech-generating technology has recently been combined with hi-tech visual scene displays in order to promote effective functional communication for persons with ABI. This technology can be created using computer software to display a scene or an event from the individual's life onto a computer, SGD, or tablet screen. When an individual clicks on a certain location on the screen, called a hot spot, the computer utilizes speech-generating software to state a relevant word or phrase. For example, when the image of an airplane is selected the phrase, "I like to watch airplanes" may be generated. As in the low-tech counterpart, hi-tech visual scene displays are designed to facilitate and structure conversations.

McKelvey et al. (2007) evaluated the use of a visual scene display on a portable speech-generating device on behaviors associated with communication breakdowns. The participant was a 61-year-old man who had sustained a stroke and had aphasia and apraxia of speech. The visual scene display software presented a single page that contained personally relevant, contextually rich photographs, text boxes describing the photos, and speech buttons. When the participant touched the speech box, a digitized speech message of the text in the text box was produced. The participant engaged in conversations with unfamiliar partners in the presence and in the absence of the visual scene display software. Data were collected on the frequency of specific communication breakdown behaviors including self-talk, discussion of his disability and difficulty communicating, and inappropriate questions/responses. Results suggest that when the visual scene display software was in use, fewer communication breakdowns occurred as compared to when the software was absent. These preliminary findings suggest that individuals with ABI may be able to improve the quality of their communication interactions through the use of visual scene displays. This is a cutting edge area of research, however, and more data are needed to make conclusive statements regarding the use of this technology.

Summary. Both low-tech and hi-tech AT has been shown to augment or provide an alternative means of communication for persons with ABI. When determining what type of AT to use to support the individual's communication skills, clinicians should consider the cognitive as well as motor skills of the individual with ABI. For example, clinicians should assess the patient's cognitive skills to determine if there is a match with the skills needed to navigating a dynamic display screen for a hi-tech speech-generating device. As many of the AT used to support communication require manual activation (SGD or letter boards) it is important to consider the patient's fine motor abilities to ensure that they will be able to independently utilize the AT to compensate for communication deficits. For persons with limited mobility, a microswitch that is activated by small movements may be appropriate (Lancioni et al. 2009b). The studies reviewed here also suggest that incorporating contextualized, personally relevant images may support effective communication in persons with ABI.

Leisure Skills

Individuals with ABI may experience difficultly in independently engaging in leisure activities for a variety of reasons. Persons with ABI may have memory or other cognitive deficits which make scheduling, planning, and carrying out leisure tasks at the correct time difficult (Hutchinson and Marquardt 1997). Individuals with more severe ABI may lack the ability to interact with stimuli in the everyday environment due to severe physical, communication, or cognitive deficits. Individuals with severe and persistent impairments are largely dependent on caregivers (Chua et al. 2007). For these individuals, interventions primarily rely on the use of high-tech AT (see Lancioni et al. 2010a for a recent review). Hi-tech AT to support leisure skills includes microswitches, virtual reality, prompting systems, and adapted household equipment. We provide a brief review of some of the research in each of these areas below.

Microswitches. Teaching individuals with ABI to use a microswitch to activate environmental stimulation may contribute to an increased awareness of the effects their own behaviors have on the environment and others, thus leading to improved consciousness and engagement (Canedo et al. 2002; Lancioni et al. 2009b; Naudé and Hughes 2005; Watson et al. 1999). Microswitch systems have been used with positive effects on engagement with environmental stimuli for children and adults with severe and multiple disabilities in a large number of studies (e.g., Lancioni et al. 2006, 2007, 2008, 2009a, c) and has more recently been shown to result in positive outcomes for individuals with severe ABI (Lancioni et al. 2010a, 2011a, b, 2012a, b, 2013).

Lancioni et al. (2011c) assessed whether a technology program consisting of a microswitch and a computer program would increase participants' access to preferred environmental stimulation. Three adults ages 53, 62, and 42 years who had severe TBI or ABI participated in this study. At the time of the study, all participants had extensive cognitive and motor impairments and received treatment at a rehabilitation clinic. An assessment of responses for each participant was conducted and microswitches were designed to fit these responses. Responses included eyelid closure or double eyelid closures. Microswitches consisted of optic sensors directed toward the participants' eye. The microswitch was linked to a computer system in order to provide participants with 20 s of access to the stimulation they selected, and to deliver a prompt to participants reminding them that they could use the microswitch to contact environmental stimulation. The stimulation samples consisted of preferred (e.g., family members talking, clips of music or videos) and non-preferred (e.g., distorted sounds) audio and or visual stimuli. Results showed that all participants used the microswitch to access stimulation and that each participant requested more access to preferred, as compared to non-preferred, stimuli. These findings suggest the individuals with severe ABI may be able to use microswitches and computer programs to access preferred stimulation.

Individuals with ABI have also been taught to activate multiple microswitches using different movements in order to access a variety of stimulation. Lancioni et al. (2010b) taught two adults with severe ABI and minimal movement to use two microswitches using different motor responses. For the first participant, motor responses included moving her finger and slightly nodding her head. For the second participant, motor responses included eyelid movements and hand stroking/pushing. Each microswitch triggered 10–15 s of access to either preferred music or a preferred movie. Results showed that both participants were able to engage in two responses to activate microswitches to access preferred stimulation. The authors suggested microswitches which enable persons with severe ABI to access preferred stimulation and to have some control over their environment may be one means of increasing the individual's awareness of his/her surroundings and decreasing social isolation for this population (Lancioni et al. 2010b).

Virtual reality. Virtual reality (VR) is another emerging technology for assisting individuals with ABI. VR interventions use computer-generated environments that allow individuals to interact with a three-dimensional world in real time. Depending on the technology utilized, individuals may view themselves immersed in the virtual environment in a way that closely approximates real life (Broeren et al. 2008; Crosbie et al. 2007; Henderson et al. 2007). Because VR closely simulates experiences individuals might have in community settings (e.g., shopping, having a check-up at a doctor's office, or operating a vehicle) it may offer a safe, controlled means of helping the individual regain skills that have been impacted by ABI. To date, much of the work in this area has examined whether and how individuals with ABI can interact with VR simulations, rather than on the role of VR in achieving restorative goals (Kang et al. 2008; Lengenfelder et al. 2002; Schultheis et al. 2007; Wald et al. 2000; Wald and Liu 2001).

Fong et al. (2010) evaluated the use of a 3-week virtual reality intervention with 10 individuals with ABI using a pre-test post-test design that matched participants (on age, gender, education level, and baseline cognitive performance) to either computer-assisted instruction (CAI) or the VR program. The VR program used a touch screen format and offered participants opportunities to manipulate all aspects and objects (card, receipt, and cash) involved in ATM transactions. The VR program allowed the researchers to assess the performance of participants on a task analysis checklist for withdrawing and transferring money using a real ATM. Data were also collected on the duration of completing the task, the percentage of errors on the task analysis, and the level of prompting required. Findings showed that the task duration of cash withdrawals was significantly shorter in the group who participated in the VR program than the CAI group. There was no significant difference between the two groups on reaction time or accuracy with money transfers. These findings suggest that VR program may be used to design instructional and practice opportunities for individuals with ABI that are at least as effective as other commonly utilized instructional strategies (e.g., CAI).

Cox et al. (2010) utilized VR to teach driving skills to military personnel with TBI. Eleven males with TBI participated in the study in either the control group or the VR group. The control group received residential rehabilitation including speech, occupational, and psychological therapy. Participants in the VR group received between four and six 60 to 90-min training sessions using a VR driving simulator. The VR simulator included 180° view, rear and side view mirror images, turn signal, brake and gas pedals, and a steering wheel. In the VR driving simulator, participants were exposed to various driving scenarios including rural roads, highway, and urban driving. Participants in the VR group received direct instruction and practice in several behaviors needed for successful driving such as maintaining center lane position, appropriate use of brakes, appropriate use of turn signal, and use of side/rear view mirrors. Participants from both groups were assessed pre and posttreatment on one driving scene of the VR driving simulator. A trained observer rated each participant's driving skills using a 5-point scale. Results showed that driving performance for the VR group significantly improved from pre-test to post-test. However, it is unclear if repeatedly practicing driving skills using VR program or the prompting/direct instruction piece led to improved driving skills as the control group did not receive any driving instruction. Notwithstanding this omission, this study does speak to the possible promise of VR in rehabilitating leisure skills for individuals with ABI.

Adapted household equipment. Lancioni et al. (2010c) taught a 46-year-old man with ABI to independently operate his television in order to view television programs. The researchers modified the television by connecting two microswitches and an amplified MP3 player to the TV. One microswitch allowed the participant to turn the TV on and off while the other microswitch enabled the participant to change the TV channels. By combining AT with the television the participant was able to change channels and turn the television on and off.

In addition to modifying televisions, microswitches have also been used to modify other household leisure items such as radios. Lancioni et al. (2012a) utilized a non-concurrent multiple-baseline design to examine the effects of teaching three post-coma adults to operate a modified radio device using a microswitch on participant responding. During baseline a conventional radio was available and the participants were told to tell the research assistant if they wanted to listen to another station, but none of the participants asked to change the station. Intervention simply consisted of five sessions (each session 30 min maximum) when the participants were allowed to experience the various options of microswitch activation and the radio stations (e.g., love songs, talk shows). Following intervention, each participant learned to operate the radio device by starting, stopping, and changing stations. Every 3 minutes, a prerecorded message asked the participant if s/he wanted to continue listening to a particular station. Participants appeared to demonstrate preferences for some radio stations over others, because they stayed on some stations longer than others and ended some sessions before the maximum allotted time. These findings indicate that the use of microswitches may facilitate engagement in everyday leisure activities and allow such individuals to express choice of activities for post-coma participants with significant motor and communication deficits.

Due to the motor impairments associated with severe ABI, clinicians should assess the individual's repertoire of motor responses and carefully consider the type and position of AT, such as microswitches. Indeed, microswitches are sometimes custom designed especially for an individual for whom available microswitches are not easily activated (Holburn et al. 2004). For instance, Lancioni et al. (2010c) developed a novel microswitch for a woman with ABI and profound and multiple disabilities so that she could access preferred stimuli. This woman's trunk, head, and limbs were static, but her mouth remained semi-open and she would briefly open or close her mouth. The microswitch consisted of optic sensors (i.e., infrared light-emitting diode and mini infrared-light detection unit) attached to her chin in such a way as to detect changes in lip positions. To evaluate the effectiveness of the microswitch, an ABAB design was used where A was baseline (microswitch available, but activation did not produce contingent stimulation) and B was intervention (use of microswitch resulted in 10–15 s contingent access to music or family voices). Differences between baseline and intervention response frequencies were found to be statistically significant ($p < .01$). These results demonstrate the effectiveness of an individualized microswitch intervention for individuals with few or singular bodily movements.

Summary. AT has been successfully used to support leisure skills with individuals with ABI. The use of assistive technology to enable individuals with ABI who have severe and persistent motor and communication impairments to access sensory stimulation is a promising intervention to improve arousal and engagement with environmental stimuli, and decrease withdrawal. This type of intervention is notably the first to allow such individuals, who are generally dependent on caregivers, to exert control over their environments in ways that improve their quality of life through access to activities that are enjoyable. Small improvements in a person's ability to independently interact with the environment and exert choice may prove to be pivotal in rehabilitation efforts for this population. However, future research is needed to further document the effects and limits of assistive technology for individuals who are minimally conscious or emerging from a minimally conscious state. For persons with mild to moderate ABI, the use of virtual reality is promising. VR may afford individuals with ABI a safe, yet realistic environment to practice and acquire leisure skills and skills needed for daily living (e.g. Fong et al. 2010). Future research is needed to explore additional uses of AT to support leisure skills in persons with ABI.

Vocational Skills

ABI impacts cognitive, physical, and emotional functioning, and as a result may dramatically affect one's ability to gain and maintain employment. In 2005, 42 % of individuals with ABI were unemployed as compared to a 9 % unemployment rate in the general population (Doctor et al. 2005). This high unemployment rate is likely due to the barriers individuals with ABI face in returning to and maintaining work (van Velzen et al. 2011). For example, individuals often experience greater post-injury fatigue that may impact their ability to work for successive hours (van Velzen et al. 2011). In addition, coordination, balance, and mobility may be compromised, prohibiting an individual from performing physical tasks in an employment setting while memory deficits may impede one's ability to remember what tasks need to be completed and how to complete them. Of those individuals who do obtain paid or supported employment, supports may be necessary to compensate for their skill deficits. In fact, it is estimated that 75 % of individuals with ABI who obtain employment or return to employment post injury will lose their job within 90 days unless they are provided with accommodations and supports, including AT (National Association of State Head Injury Administrators 2006). However, a records review of a sample of individuals with TBI enrolled in public rehabilitation services showed that of those persons who were provided AT in their workplace, 73 % were employed as compared to only 49 % of individuals with TBI who were not provided AT (Gamble and Satcher 2002). Below we provide descriptions of research evaluating the use of low-tech and hi-tech AT to support vocational outcomes.

Much of the AT supports for vocational skills are designed to compensate for cognitive skill deficits. This is likely due to the fact that vocational behaviors rely on memory. For individuals with mild to moderate ABI, memory notebooks, calendars, and alarms can be used to assist employees with ABI to complete job tasks. Because low-tech AT often consists of everyday materials, such as checklists or visual cues, their use may have a more natural fit within the work environment.

For persons with ABI who have resulting physical or sensory disabilities or limited mobility, adapted or modified equipment may enhance their ability to perform job-related tasks. For example, enlarged keyboards or enlarged computer monitors may support an individual who has difficulty with fine motor movements or vision. In addition, AT to augment communication skills, such a voice amplification devices may be beneficial in a work environment when interacting with fellow employees, supervisors, or customers. Other AT, such as mouthsticks or headpointers, may allow individuals with limited mobility to complete tasks such as answering the phone or typing on the computer (Inge et al. 2000).

Lund et al. (2011) conducted a qualitative, multiple case study with 10 adults with ABI and their significant other or family member. Participants (6 men, 4 women) were registered with a brain injury rehabilitation center in Sweden. Participants were between the ages of 33 and 59 years. Three participants were employed at the time of the study, and the other seven had temporary or permanent disability pension. All participants had received occupational therapy with a focus on the use of low-tech AT to support daily living and/or vocational goals. Vocational goals included such behaviors as arriving to work on time and completing job-related tasks without the help of another adult. Participants were interviewed for one hour regarding the type of AT they have used and the impact the AT had on their lives and the lives of their significant other/family member.

All participants with ABI reported that when they were taught to use low-tech AT, they were more independent and could complete tasks that they otherwise could not. Significant others/family members reported that they had reduced responsibility and stress when their family member was using AT. All participants reported an increased quality of life as a result of the use of AT to support daily living and vocational behaviors. Although these findings are qualitative, they suggest that AT may impact other areas of life, such as independence and happiness. Future quantitative research is needed to systematically examine the impact of AT on quality of life and employment for persons with ABI.

With the increased availability and use of technology, such as Smartphones or paging systems, individuals with ABI may be able to successfully complete vocational skills. Access to cognitive supports in community settings has been shown to improve performance in workplace settings, and increase in self-reported quality of life (Gentry et al. 2008). Hi-tech AT may help individuals with ABI to complete tasks such as attending meetings on time, taking notes during meetings and recalling tasks and appointments (Linden et al. 2011).

Hartmann (2010) presented a case study on the effects of AT on vocational skills with a 32-year-old man with mild TBI. Prior to the brain injury incident, the participant was a college graduate and employed full time as a paralegal. He sustained a head injury during a racquetball game that resulted in brief loss of consciousness. Following the incident, the participant experienced difficulties reading, staying on task, and interacting appropriately with other workers at his place of employment. In an attempt to improve the participant's performance at work, a variety of AT tools were presented to the participant. The participant selected four AT tools including text-to-speech software, a digital pen and specialized paper that allowed handwritten notes to be converted into a word processing document, the use of Microsoft PowerPoint to organize information, and a portable handheld dictation device. The participant was reported to successfully use these AT tools in his employment. The author reported that with the use of AT, the participant's work production returned to pre-injury levels. However, given the limited amount of research studies examining AT in support of vocational outcomes for persons with ABI, more rigorous empirical research is needed.

Handheld electronic devices. PDAs are one example of an unobtrusive handheld electronic device that can be used in employment settings. Gentry et al. (2008) provided PDAs and training to 23 adults with TBI who had difficulty performing tasks at work due to cognitive deficits. Participants were taught how to enter appointments into their PDA, how to enter and manage the calendar and alarm settings, and how to update the address book and the “to do” list feature of the PDA. Participants were taught to use the PDA over the course of three to six 90-min home visit sessions. Following this training, participants were to use their PDA for 8 weeks. Prior to and following the PDA training, participants and their caregivers rated participant performance at work and their satisfaction with their performance at work. Results showed statistically significant improvements in ratings on these measures 8 weeks following the PDA training. However, observational data on work performance pre-and post PDA training were not obtained. So, while PDAs appeared to have high social validity among participants in this study, more research is needed to evaluate the impact of PDAs on vocational behaviors for individuals with ABI.

Summary. Although there are a number of barriers to employment for individuals with ABI, returning to work is one of the most common goals for individuals with ABI (Velzen et al. 2011). Studies have shown that individuals with severe ABI can return to work when given proper supports (Inge et al. 2000). There is research to suggest that incorporating AT into employment is associated with an increased sense of satisfaction and quality of life for persons with ABI (e.g., Gentry et al. 2008). However, rigorous, experimental research is needed to evaluate the impact of AT on job performance, job attainment, and the maintenance of employment.

Implications for Practice

Empirical research has shown that AT is a very effective method for addressing compensatory goals for individuals who have ABI. Yet, AT, particularly hi-tech AT, is not often used in practice (Sohlberg and Mateer 1989). There are numerous barriers to the use of AT by consumers (Gartland 2004; Lemoncello et al. 2011) and research indicates that few people are using electronic memory aids and instead rely on low-tech memory aids (Evans et al. 2003). Barriers may include the complexity of using the AT device and the availability and cost of the device. In addition, use of the device may require additional resources such as batteries, technical support, and/or extensive training (e.g., Lemoncello et al. 2011).

The adoption of AT by clinicians and consumers requires considerable clinician expertise to (a) conduct assessment to match and adapt technology to user’s cognitive, communication, physical, sensory and motivational profile (LoPresti et al. 2004; Sherer et al. 2005) and (b) to design and implement systematic instruction so that the consumer and caregivers can effectively learn to use device (Kapur et al. 2002; McBain and Renton 1997; Powell et al. 2012; Singh 2000), especially for consumers who lack experience with technology (Vaccaro et al. 2007), or experience frustration when the AT responds in an unanticipated manner (de Joode et al. 2012b).

Assessment before selecting a device and periodic assessments after the device is in place may assist in determining if the AT is functioning as intended, being used regularly, or if changes/adaptations, reassessment need to occur. Assessing good fit between an electronic aid and a user is difficult as there are few available assessment tools that assess cognitive abilities in relation to AT use (Gillette and De Pompei 2004). Depending on the technology being used, some individuals with ABI may also require additional skill instruction to acquire prerequisite skills, such as literacy skills to utilize reminders via a smartphone. This is sometimes complicated by clinician's sometimes lack of knowledge, experience and training with AT devices (Gartland 2004; Hart et al. 2003), the high cost of technologies and lack of routes to reimbursement (Gartland 2004; LoPresti et al. 2004) and the usability, feasibility, portability of devices, and availability of ongoing technical support (Hart et al. 2004). However, these barriers may be shifting due to the increasing availability of electronic technologies such as computers, PDAs, and smartphones to the general public and their use by individuals with and without disability (Bryen et al. 2007). The use of generic, readily available technologies such as smartphones may result in decreased cost and improved use by individuals with ABI because such AT is socially valid and their caregivers and clinicians may have more experience with such devices (LoPresti et al. 2004).

Implications for Research

Although the research exploring the use of AT to support individuals with ABI is extensive and generally reports positive outcomes, these finding should be interpreted with caution. Many studies in this area utilize case studies that lack experimental control (e.g., McDonald et al. 2011). A recent review of AT across disability categories associated with cognitive deficits demonstrated that the certainty of evidence of these studies is lacking according to widely held guidelines regarding quality and rigor of experimental design (Gillespie et al. 2012). In order to provide more conclusive demonstrations of the impact of AT on the skills of individuals with ABI, more rigorously designed studies are needed. The use of strong single-subject research designs, such as alternating treatments or reversal designs, lends itself to the individualized nature of providing treatment of persons with ABI while also demonstrating experimental control (e.g., Lancioni et al. 2010c). Researchers have called for improvements to the quality of single-subject research on AT by including multiple data points across experimental phases, using standardized outcome measures, inter-rater reliability and the use of blind raters, and using statistical analysis in addition to visual analysis (Gillespie et al. 2012).

The extant research on AT with individuals who have ABI has addressed compensatory goals. Future research is needed to determine if and how AT can be used to restore skills and behaviors previously within the repertoire of individuals with ABI. Technology systems, such as virtual reality, are rapidly expanding and may lend themselves to such endeavors.

Research is also needed to examine issues related to the maintenance of AT use over time. Currently, most studies have taken place in highly controlled environments, such as hospitals or rehabilitation centers. Empirical data on the use of AT in more natural environments, such as homes, community, or vocational settings is needed in order to better understand the feasibility and suitability of these technological supports. In addition, much of the research to date has evaluated immediate or short-term use of AT and studies evaluating the long-term use of AT by persons with ABI are needed. Future research should also examine whether, and under what conditions, persons with ABI use AT to compensate for skill deficits.

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Chapter 3
Assistive Technology for Postsecondary Students with Disabilities

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Introduction

Completing a postsecondary education (i.e., obtaining a degree from a college, university, two-year community college, or vocational school) has been shown to dramatically increase the likelihood of a person obtaining a job, regardless of whether or not that person has a disability (Hutcheon and Wolbring 2012; Rath and Royer 2002; Stodden et al. 2001, 2003; Tagayuna et al. 2005). In fact, the positive correlation between postsecondary education and employment might be stronger in people with disabilities than in the general population (Burgstahler 2003; Stodden et al. 2003). Individuals with a disability that complete high school degrees have an estimated employment rate of 30 %, but those that go on to complete a postsecondary degree have an employment rate of approximately 50 % (Yelin and Katz 1994a, b).

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Improved employment opportunities, in tandem with supportive legislation in some countries, are likely responsible for the increasing number of people with various learning, developmental, and physical disabilities seeking postsecondary degrees (Day and Edwards 1996; Parker and Banerjee 2007; Stodden et al. 2001). In the United States, for example, as many as 9–17 % of college students report having a disability, with the most common being a learning disability (e.g., dyslexia) (Quinlan et al. 2012; Rothstein 2006). In Canada, the number of college students with a learning disability alone may be as high as 36 % (Holmes and Silvestri 2012). The high percentage of people with disabilities enrolled in postsecondary institutions might not hold internationally, but even in regions of the world where far fewer people with disabilities attend college, there still appears to be an increasing desire to support the students with disabilities that do matriculate (e.g., Heiman and Shemesh 2012). For example, Ari and Inan (2010) reported that only 0.08 % of students entering universities in Turkey have identified disabilities, but they also describe an emerging societal emphasis toward encouraging people with disabilities to strive for independence that is consistent with the aim of increasing the number of students with disabilities enrolled in higher education.

People with disabilities attending postsecondary institutions are likely to face a number of obstacles and challenges beyond those faced by individuals without disability (Hutcheon and Wolbring 2012). For example, individuals with physical disabilities may require support to access buildings and materials (e.g., books on a high library shelf). Individuals with visual or hearing impairment may need alternative methods for utilizing printed materials, Internet content, and spoken lectures (Lartz et al. 2008; Moh 2012). Finally, individuals with learning and/or developmental disabilities may require additional supports to address instructional needs and/or navigate complex social situations (Gobbo and Shmulsky 2012; Green 2009; White et al. 2011).

Given the increasing enrollment of people with disabilities in postsecondary institutions and their associated needs, it is not surprising that postsecondary institutions are looking to technology to mitigate the obstacles impeding the success of these students (Holmes and Silvestri 2012; Martinez-Marrero and Estrada-Hernandez 2008; Stodden et al. 2001). Technology appears to be increasingly commonplace in postsecondary institutions worldwide perhaps because it is seen as one way to improve efficiency of instruction and to increase access to a large volume of learning materials. For example, laptops are now commonly used for taking notes, email is used for efficient correspondence with instructors and between students, the Internet allows students to locate print resources from places outside the postsecondary institution, and distance learning programs are being used to bring students to virtual learning environments from geographically distant locations (Guyer and Uzeta 2009). In modern postsecondary institutions, these technologies are often available to students regardless of the presence or absence of a disability.

Assistive technology (AT) differs from typical applications of technology in that AT is specifically used to enable students with disability to access the same materials and environments as students without disability. Bryant et al. (2010) quote International Business Machines (IBM 1991) to highlight this point: "For people without disabilities, technology makes things easier; for people with disabilities, technology makes things possible" (p. 203). For the purpose of this chapter, AT will refer to any item, device, or piece of equipment specifically designed or used to meet the needs of a person with a disability by augmenting or enabling their functional capabilities and/or their access to specific environments, information, or other instructional materials (cf., Bryant and Bryant 2003; Martinez-Marrero and Estrada-Hernandez 2008).

First, this chapter will review research aimed at identifying the various types of AT available to students with disabilities, and the three most common forms of AT identified will be described in detail. Second, intervention research evaluating student outcomes following the provision of AT will be reviewed. Finally, reasons why AT may be difficult to obtain will be discussed, and recommendations for professionals charged with supporting the AT needs of postsecondary students will be offered. Ultimately, the aim of this chapter is to inform decisions concerning AT for postsecondary students and to elucidate directions for future research.

Types of Assistive Technology Available to College Students with Disabilities

There is such a wide array of AT potentially available to postsecondary students with disabilities that a complete description of all the possible forms and functions is not practical within the intended scope of this chapter. However, several recent research studies have attempted to identify the most common forms of AT utilized in postsecondary degree granting institutions. These forms of AT, the area of disability they are used to address, and a brief description of how the AT works is provided in Table 3.1. Table 3.1 was created by searching the electronic databases PsycINFO and Educational Resources Information Clearinghouse (ERIC) using key terms related to postsecondary education (e.g., college and university), disability (e.g., dyslexia), and AT. The types of AT identified in the studies that resulted from this search were used to create Table 3.1 (e.g., Holmes and Silvestri 2012; Ofiesh et al. 2002; Sharpeet et al. 2005; Tagayuna et al. 2005; Thompson et al. 2010; Webb et al. 2008). Two of the studies used to create this table are then discussed in additional detail (i.e., Ofiesh et al. 2002; Sharpe et al. 2005). Finally, the three forms of AT found to be among the most prevalent are described in more detail (i.e., voice recognition systems, reading machines, and frequency modulated listening devices).

Ofiesh et al. (2002) conducted a survey of members of the Association on Higher Education and Disability (AHEAD) that were also service coordinators for students with disabilities at 2-year community colleges, vocational-technical colleges, or 4-year universities and colleges in the United States. A total of 366 surveys were

Table 3.1 Types and function of assistive technology available to postsecondary students

Area of disability	AT used to address area of disability	Description of AT function
Writing/Spelling	Spell and grammar check software	Identifies and corrects spelling and grammar errors in digital text
	Abbreviation expansion software	Translates abbreviations to words and vice versa in digital text
	Word prediction software	Completes typed words based on beginning of words (e.g., "soci" becomes "social")
	Voice recognition software	Removes need to handwrite or type by producing digital text from speech
	Tape recorder or similar digital recording device	Records speech and translates into text, removing the need to handwrite or type lecture notes
	Macros	Simple combinations of letters that can generate whole words with fewer keystrokes
Reading	Screen reader software	Produces speech from digital text presented on computer
	Large screen computer monitors, screen magnification software, and handheld magnifiers	Enlarges text
	Talking dictionary	Defines and pronounces words
	Optical character recognition systems	Produces digital text from handwritten text and other print sources (e.g., newspapers)
	Audio recorded text	Vocalizes the recorded text, removing the need to read text
	Written text translated to braille	Enables reading via touch
	Reading pen	Handheld optical character recognition device that allows students to scan printed text one word or line at a time. Scanned text can then be converted into speech
Math and science	Modified lab equipment	Adaptations made to scientific equipment to accommodate for physical disabilities (e.g., chemistry beakers with larger handles that are easier to hold)
	Mathematical symbol speech recognition software	Produces speech corresponding to mathematical concepts and vice versa
	Talking calculator	Vocalizes the numbers entered, commands, and output reducing the need to see the screen

(continued)

Table 3.1 (continued)

Area of disability	AT used to address area of disability	Description of AT function
Computer use and Internet access	Enlarged cursor	The cursor indicating where on the screen an intended action (typed word) will take place within a document is larger and easier to see
	Screen magnifier	Enlarges text on websites
	Screen reading software	Reads text from websites
	Specialized input devices	Allows for input in the form of eye movement, speech, or some other body movement individualized to the abilities of the user
Speech	Speech generating device	Creates audible speech from typed messages, eye gaze detection, or some other form of user input
Organization and self-management	Digital calendars and day planners	Stores appointments, important deadlines, and similar information electronically
	Concept mapping and/or outlining software	Provides prompts and guidance to understanding intricate interrelated academic concepts
	Noise blocking headset	Prevents user from hearing distracting background noise
	Online scheduling and planning websites	Helps plan and organize meetings, classes, and other activities involving groups of people and/or multiple commitments

sent out and 163 were returned with useable data (45 % response rate). The most commonly identified disability category requesting services was learning disability ($n = 111$) and the smallest was visual and hearing impairment ($n = 12$). Although people with visual/hearing impairments were the smallest group, they were the group with the highest percentage of students utilizing AT. Individuals with psychiatric disabilities were the least likely to request AT. The most common forms of AT identified by service coordinators were voice recognition systems ($n = 185$), reading machines ($n = 104$), frequency modulation (FM) systems ($n = 79$) and text enlargement systems ($n = 64$). Findings of this survey also indicate that many forms of AT are used across disability categories. For example, people with visual impairment, learning disabilities, mobility impairment, and psychiatric disability use voice recognition systems. This pattern of use across disability category was also identified in regards to reading machines, text enlargers, and closed-circuit television.

Sharpe et al. (2005), among other goals, also sought to identify the most common forms of AT provided to postsecondary students. They interviewed 139 (59 % female) postsecondary students with disabilities attending 2-year and 4-year postsecondary institutions. Respondents were asked to identify their primary disability, and learning disability (33 %) followed by Attention Deficit Disorder (ADD) (23 %) were the most frequently reported. It is notable that 27 % of respondents reported being diagnosed with more than one disability. Additionally, 40 % of the respondents reported having their disability first identified after they began their postsecondary education. Among the subset of students with disabilities that were first identified while attending a postsecondary institution, the most common disability was Attention Deficit/Hyperactivity Disorder (ADHD). The most frequently used types of AT identified by Sharpe and colleagues were scanners used to digitize text (35 %), talking books (20 %), note-taking devices (15 %), tape recorders (12 %), and voice recognition software (12 %). All other forms of AT were used by less than 10 % of respondents.

Voice Recognition Software

Voice/speech recognition software was identified in several studies as one of the most prevalent forms of AT available to postsecondary students (Ofiesh et al. 2002; Sharpe et al. 2005). Speech recognition systems typically involve a desktop computer or laptop with a soundboard, microphone, and specialized software. This arrangement enables a user to operate a computer with voice commands, eliminating the need for the fine motor movement inherent to typing and reducing reliance on spelling and reading. Speech recognition systems are of potential value to individuals with visual or motor impairments, as well as disabilities in which skills in oral expression exceeds that of written expression (Raskind and Higgins 1998). Depending on the processing speed of the computer, these programs are capable of converting more than 70 words per minute from speech to text. Modern versions of this software have the ability to "learn" an individual's accent, speech patterns, and other voice characteristics over time. This attribute enables the software to become increasingly user-friendly with continued use.

Screen Reading, Speech Synthesis, and Reading Machines

Screen readers (and other similar devices) produce synthetic speech from digital text. For example, text on a computer screen can be read aloud enabling students with a visual impairment or a learning disability that influences reading (e.g., dyslexia) to access the written material more easily. Some versions of this AT allow the user to select between a digitized mechanical sounding voice and a more human or natural sounding voice and, in some cases, further selecting between accents and male or female voices. This feature allows the user to select the output voice that is the most easily understood or pleasing. These software programs can be used in conjunction with typical scanners or optical character recognition devices to turn printed text into digital text that can then be read aloud. For example, Schmitt et al. (2012) describe a "Reading Pen" that utilizes optical character recognition (OCR) software in a handheld device shaped like a pencil that enables a student to scan printed text using the same motion required to use a highlighter. The scanned text can then be displayed on a computer screen and converted into speech.

Frequency Modulated (FM) Listening Systems

FM systems provide support for individuals that experience difficulty hearing lectures due to a sensory impairment or difficulty paying attention to auditory input due to disabilities such as ADD. FM systems typically consist of a microphone connected to a transmitter on the speaker's end and a receiver with a headset or earphones on the listener's end (Raskind and Higgins 1998). Omnidirectional microphones can be used to accommodate situations involving multiple speakers. The listener can control the volume to meet their specific needs, and recording devices can be inserted in the loop to create a recording in lieu of taking hand-written or typed notes.

Intervention Research Evaluating Assistive Technology

Intervention research has evaluated the potential benefits of AT for postsecondary students with disabilities. Table 3.2 is a summary of this intervention research and was created by searching the electronic databases using procedures similar to those

Table 3.2 Intervention research involving assistive technology for postsecondary students

Citation	Participants	Assistive technology used	Research design	Outcomes
Floyd and Judge (2012)	Six postsecondary students with LD[1], between the ages of 18 and 22-years old ($M = 19.5$ years)	A portable text reading machine (i.e., "ClassMate Reader")	Multiple baseline across participants	The percentage of reading comprehension questions answered correctly improved for five of the six participants and appeared to have little or no impact on the sixth participant
Foley (2011)	two postsecondary students with a visual impairment, one student with dyslexia, and one with an unspecified LD	Screen reader and screen magnifier	Data on where students clicked and how they navigated a test website were analyzed and considered in tandem with interviews and in vivo observation	Automated validation tools within a website do not ensure complete accessibility for all students. Ultimately, results suggest that the usability and accessibility of a website varies within and across disability categories
Graves et al. (2011)	A total of 11 postsecondary students including five with LD, four with ADHD[2], and two with both ADHD and LD	Asynchronous online access to class recorded lectures using Tablet PCs[3]	Qualitative study involving data collected using semi-structured interviews was analyzed and compared using a cross-case analysis	All students reported positive results, specifically, the AT was found to facilitate learning in STEM courses by: (a) enhancing clarity of course concepts, (b) improving organization of course materials, (c) providing asynchronous course access, (d) and increasing convenience
Heiman and Shemesh (2012)	A total of 964 postsecondary students (M age = 28.5 years old) participated. The treatment group contained 363 participants with LD, and the control group contained 601 without LD	Specific forms of AT were not reported	Qualitative study using the following questionnaires: (a) *Perceptions of Learning through Online Usage*, (b) *Accessibility of Campus Computing*, (c) *Hope Scale*, and (d) *Subjective Well-being Scale* in tandem with a detailed examination of the usage patterns during online courses	Students with LD are more familiar and comfortable using AT and report using it more frequently than students without LD. Students with LD reported a greater desire to identify alternative ways to meet their learning objectives than students without LD

(continued)

Table 3.2 (continued)

Citation	Participants	Assistive technology used	Research design	Outcomes
Higgins and Raskind (1997)	37 postsecondary students with LD (*M* age = 24.9 years old)	OCR[4] system (i.e., Hpscanjet Arkenstone reader and Arkenstone conversion software)	Reading comprehension was evaluated in three test conditions: (a) using OCR and speech synthesis, (b) text read by human reader, and (c) no human or AT assistance	A significant inverse correlation between scores obtained in silent reading comprehension and OCR reading comprehension was identified. OCR technology raised reading comprehension scores for some students but interfered with performance for others resulting in lower scores
Klemes et al. (2006)	A total of 24 postsecondary students including 14 students with ADD[5] and 10 with LD and ADD	Acrobat 4.5 ME® was used to present the text synchronized with speech output	Qualitative design involving structured telephone interviews and an attitude questionnaire	Students with LD need less time to read a text when it is synchronized with auditory presentation
MacLeod (2010)	Seven postsecondary students with Asperger's syndrome	An online network of college students with Asperger's syndrome enabled online discussion of topics relevant to Asperger's syndrome (AS Portal)	Interviews and discussions with participants following use of the AS Portal	Overall students found the AS portal to be valuable and provided the following feedback: (a) the group should be limited to students from the university with an ASD, (b) portal should contain discussion forum, links to other useful sites (as opposed to duplicating content from those sites), study skills advice, and training resources for university staff (c) visual appearance of website is important, and (d) the portal should have a clear university affiliation
Neely (2007)	15 postsecondary students with one or more of the following diagnoses: cerebral palsy, low vision, paralysis, blindness, and loss of mobility due to injury; specific number for each disability type was not reported	AT designed to help students complete tasks in a chemistry lab, for example; low profile mobile lab table, magnification systems, adapted pouring beakers, Braille labeler, texture 3-D paints and other similarly adapted equipment relevant to chemistry lab	Comparison of written and verbal comments collected from faculty and students after the lab experiments without AT (phase 1) compared to after the lab activities with AT (phase 2)	The adaptations were considered appropriate and useful. Suggestions from the students with disabilities improved the lab environment for both students with and without disabilities

(continued)

Table 3.2 (continued)

Citation	Participants	Assistive technology used	Research design	Outcomes
Obringer et al. (2007)	One postsecondary student with spastic quadriplegic cerebral palsy	Intellikeys, keyguard, and Co-Writer	Randomized block design in which three keyboarding AT systems were layered to determine the contribution of each AT individually and collectively for improving keyboarding accuracy	In the Intellikeys alone condition typing accuracy increased from 48 % in the 1st trial to 81 % in the third trial. In the Intellikeys plus keyguard condition accuracy increased from 84 % in T1 to 92 % in T3. In the Intellikeys plus keyguard plus Co-Writer condition, accuracy increased from 93 % in T1 to 94 % in T3. Suggesting the integration of the evaluated AT systems may produce the best results
Raskind and Higgins (1995)	33 postsecondary students with LD between the ages of 19–37 years old ($M = 24.9$ years)	Screen reading software and a speech synthesis system	Pre-experimental pre/post-test design was used to evaluate students' ability to identify errors (e.g., spelling and grammar) in text using AT	Participants located a higher percentage of typographical and spelling errors in speech synthesis condition and more grammatical mechanical errors when having the text read aloud by another person. Overall, participants detected a significantly higher percent of total errors in speech synthesis condition
Roberts and Stodden (2005)	15 postsecondary students classified as "learning disabled"	Voice Recognition System (i.e., Dragon Naturally speaking V5.0)	Mixed method design involving qualitative analysis from focus groups, interviews, surveys, and observations and quantitative analysis of Fry's readability graph to provide grade level equivalence from writing samples	The student's level of need and personal issues and goals appeared to determine how beneficial the software was and how likely it was to continue being used. Variables influencing continued use included time required to use, ease of use, ease to learn, use of standard English, specific disability, and use of other forms of AT

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Table 3.2 (continued)

Citation	Participants	Assistive technology used	Research design	Outcomes
Schmitt et al. (2012)	Three postsecondary students with reading disabilities ages 20–21 years old	OCR reading pen	Alternating treatment design counter-balanced across three conditions: (a) reading pen used for decoding, (b) reading pen used for decoding and vocabulary definitions, and (c) no reading pen (control)	For two participants the reading pen did not improve comprehension of college level text. However, the participant with lowest reading comprehension appeared to benefit the most from use of the reading pen
Wessel et al. (2011)	Nine postsecondary students with physical disabilities that used wheelchairs	Power wheelchair used to play soccer in a collegiate intramural club	Data collected using semi-structured interview	Participating in wheelchair soccer positively influenced social interaction, sense of independence, self-confidence, competition and teamwork

[1] Learning disability
[2] Attention deficit/hyperactivity disorder
[3] Personal computer
[4] Optical character recognition
[5] Attention deficit disorder

described for Table 3.1. A total of 15 intervention studies involving postsecondary students and AT were identified and summarized in terms of participant characteristics, AT, research design, and outcomes. Two studies that are representative of the various approaches to intervention research in this area are then discussed in additional detail.

Across the 15 studies summarized in Table 3.2, the most common diagnosis represented was learning disability ($n = 10$ studies); however, in most cases, the specific nature of the learning disability was not reported. The exceptions are Foley (2011) and Schmitt et al. (2012) that reported diagnoses of dyslexia and learning disability in reading, respectively. The next most common disability category represented in the intervention research was ADD or ADHD ($n =$ three studies). The remainder of the summarized studies included participants with cerebral palsy (two studies), unspecified physical disabilities (two studies), visual impairment (three studies), hearing impairment (three studies), and Asperger's syndrome (one study). The diagnoses included in the intervention research appear to align with the prevalence of disabilities identified among postsecondary students identified by Ofiesh et al. (2002) and Sharpe et al. (2005). Specifically, the most common disabilities found in postsecondary students are learning disabilities and ADD or ADHD, and these are also the two most common diagnoses in the corpus of intervention research.

As indicated in Table 3.1, there are many forms of AT designed to fulfill a variety of functions. However, Table 3.2 suggests that only a relatively small subset of these AT options have been evaluated in intervention research. AT designed to read text from either printed materials or off a computer screen was the most commonly evaluated form of AT. Text reading AT was used to improve reading comprehension (e.g., Floyd and Judge 2012; Higgins and Raskind 1997), increase access to and usability of websites (e.g., Foley 2011), and increase studying efficiency (e.g., Klemes et al. 2006). All other forms of AT that have been evaluated in intervention research have been addressed in two studies or fewer; specifically, this includes devices or software designed to facilitate typing (e.g., convert speech to digital text), magnify screens, record lectures, enable participation in sports via power wheelchairs, enable participation in chemistry lab tasks, and provide access to an online support group with links to resources for people with Asperger's syndrome attending the same college.

The research designs utilized to evaluate these forms of AT included pre-experimental pre/post-test studies, experimental single case designs (e.g., multiple baseline design across participants), group designs with and without randomization and control groups, and survey research in which respondents completed questionnaires covering AT use, student perception of benefit, and educational outcomes (e.g., graduation rates). Outcomes of this body of research indicate that AT is generally beneficial but that outcomes may be dependent on many factors (e.g., disability type and severity, student skills using technology, and the opinion of instructors or classmates regarding AT). To illustrate both the complexity of results and the diversity of research designs, two of the studies summarized in

Table 3.2 are described in additional detail (i.e., Floyd and Judge 2012; Heiman and Shemesh 2012).

Heiman and Shemesh's (2012) study sought to determine: (a) the manner in which students with and without learning disability use online courses and the contribution of online courses to the students' education, (b) the contribution of AT used to facilitate instruction within an online course, and (c) the extent to which AT contributed to students' ratings of hope and wellbeing. Their study included 964 undergraduate students (mean age = 28.5-years old; 55 % male) enrolled in online courses covering sociology, psychology, education, and business in Israel. Participants were assigned to one of two groups based on the presence or absence of a diagnosed learning disability. The learning disability group consisted of 363 students (51 % male) and the non-learning disability comparison group contained 601 students (57 % male). All participants in the learning disability group had learning disabilities affecting performance in reading, writing, and/or spelling in their primary language (Hebrew) diagnosed prior to their involvement in the study. Groups were matched on gender and academic field of study. There were no significant differences between groups in terms of grade point average or previous academic credits for course completion. A battery of questionnaires aimed at determining students' perceptions of the online course, patterns of AT usage, accessibility of campus computers and websites, and students' self-ratings of hope and well-being were administered to both groups. Multivariate analysis of variance (MANOVA) was used with five dependent variables derived from the results of these questionnaires. Significant differences between groups related to the usage of the online courses were identified. Specifically, students with learning disabilities: (a) log into the course website more frequently, (b) send more messages, (c) regard the websites as a more important means to connect with other students and instructors, and (d) consider themselves to be more actively involved in utilizing the academic content of the sites than students without learning disabilities. Regarding the various AT features utilized by the website, students with learning disability report being more familiar and comfortable with the AT and using those features more frequently than the comparison group. Further, students who reported more frequent use of the website reported higher suitability of the AT to their needs, higher academic achievement, and higher ratings of the social experience than those with less usage.

In contrast to Heiman and Shemesh's (2012) large scale evaluation utilizing a combination of technologies with groups of students across multiple disciplines and a wide range of abilities, Floyd and Judge (2012) sought to evaluate a single form of AT with a small group of postsecondary students with similar abilities using a research design with strong internal validity. Specifically, a multiple baseline across participants design was used to determine the effects of a portable text reader (i.e., ClassMate Reader developed by HumanWare, Inc.). All six participants (four males) were undergraduate students between the ages of 19 and 22 years, had IQ scores above 90, attended a public university in the United States, and were diagnosed with a learning disability affecting reading comprehension. The ClassMate Reader enabled students to listen to an audio version of text while simultaneously reading along as the software highlighted the words being read. Additionally, the ClassMate Reader provides options that enable students to adjust the rate at which the text is read (i.e., words per minute), volume, color of text, font style, and highlighting colors. These options are intended to allow the student to modify the system based on their preferences. A set of 15 readings at the 11th grade reading level was counterbalanced for presentation order during baseline and intervention. During baseline, passages were presented in a paper format. Each participant was afforded as much time as necessary to read the passage. The passages were then returned to the examiner and the participant received a quiz with reading comprehension questions corresponding to the passage. After a stable pattern emerged for each participant's reading comprehension scores in baseline, participants were trained to use the ClassMate Reader and were allowed to use the system to complete additional readings and quizzes from the same pool of passages. Percentage of nonoverlapping data (PND) was calculated to compare scores across the baseline and intervention phases for each participant. Ultimately, four of the participants experienced moderate benefit (i.e., 65–85 % PND), one participant experienced only marginal benefit (less than 65 % PND), and one participant demonstrated no improvement using the AT (0 % PND).

Overall, this corpus of intervention research must be considered emerging and firm conclusions regarding any specific form of AT used to address any specific area of need or disability is not yet possible (Chambless and Hollon 1998). Given the large variety of disabilities represented in the postsecondary student population and the rapid advances in technology over the last several decades that are likely to continue in the future, it may be difficult for intervention researchers to catch-up and practical application may continue to outpace intervention research in this area (Alper and Raharinirina 2006; Holmes and Silvestri 2012).

Obstacles to the Use of AT and Recommendations

Despite the potential benefits of AT, postsecondary students often struggle to obtain AT support from postsecondary institutions. Further, even when AT is provided, it may be abandoned by the student despite continued need for support (Alper and Raharinirina 2006; Garrison-Wade 2012; Goodman et al. 2002). Table 3.3 was created using procedures similar to Tables 3.1 and 3.2. Table 3.3 summarizes seven studies in terms of their methodology and the factors that were found to inhibit adoption or lead to abandonment of AT by postsecondary students. The studies included in Table 3.3 sought to address a variety of research questions, however, only the results related to these factors are summarized.

Table 3.3 suggests that barriers to the provision and continued use of AT tend to be one or a combination of three factors: (a) student factors, (b) postsecondary institutional factors, and/or (c) factors inherent to the specific AT device or software.

Table 3.3 Reasons assistive technology is difficult to obtain or abandoned

Citation	Method	Obstacles to AT use identified
Alper and Raharinirina (2006)	Literature review of 60 articles (not all involving postsecondary students) focused on AT use by people with disabilities	High cost of AT and lack of funding Students lack of information regarding available AT options Postsecondary institutions lack information regarding AT options and their potential benefits for students with disabilities Postsecondary institutions may not provide training in use of AT or may not offer ongoing support to students using AT Lack of consideration of student-specific needs when matching an individual to a specific AT device AT factors such as: complicated procedures for setup, operation, and/or programming and issues related to portability of the AT Unreliable technology and a lack of technical support or preventive maintenance
Day and Edwards (1996)	A selective review of literature focused on AT for postsecondary students with learning disabilities	AT device operation may require skills the student lacks The postsecondary institution may not have the specific form of AT the student requires
Garrison-Wade (2012)	A qualitative study involving 59 students with various disabilities and six disability service coordinators from five 2-year community colleges and three 4-year universities in the United States. Participants were interviewed individually and in focus groups to determine factors that inhibit or enhance educational outcomes	Students indicated they were uncertain on how to obtain the services/support they required and/or were too embarrassed to request the services Some postsecondary faculty harbor negative attitudes regarding such supports/services and lacked understanding of students' needs and legal rights

(continued)

Table 3.3 (continued)

Citation	Method	Obstacles to AT use identified
Goodman et al. (2002)	A series of three interviews were conducted with 14 college students with disabilities in order to identify factors that influenced their decisions to use AT designed to support personal computer use	Lack of institutional/environmental support Personal attitudes of the student receiving AT, for example, lack of motivation to use the device due to perception of low need or device inadequacy Device aesthetics, weight, size, and appearance Change in student ability renders the device no longer necessary Lack of training to use the device (this study involved providing training to use AT related to a personal computer) Lack of information on repair and maintenance of the device
Harpur and Loudon (2011)	A survey designed to determine how students with print disabilities are supported was administered to 17 disability service coordinators and 22 librarians working in 39 universities in Australia. Data from the public websites from the same universities was also incorporated	Students with print disabilities are often not provided with the AT needed to access the written content in textbooks due to statutory issues related to copyright Lack of university policies specifically related to provision of AT services Students' delay in requesting AT Instructors' delay in assigning specific reading, which limits the time available to convert text into braille or audio

(continued)

Table 3.3 (continued)

Citation	Method	Obstacles to AT use identified
Parker and Banerjee (2007)	A survey designed to assess comfort level and fluency with technology was administered to 142 undergraduate education majors at large university in United States	Some students are not proficient with audio books and text-to-speech software Students with disabilities may experience more difficulty using email than students without disabilities
Quinlan et al. (2012)	Semi-structured interviews focused on ways instructors act that are both supportive and unsupportive of AT use with 10 postsecondary students with disabilities	Instructors may believe the AT is too helpful, reducing the learning requirements of the user to an unacceptable level Instructors may believe the disability does not exist or requires no accommodation As a result of instructor opinions listed above, students may be reluctant to pursue AT or approach an instructor about AT use in their class

Student Factors that Impede AT Provision and Use

Student-related factors that inhibit obtaining AT or that lead to early abandonment of AT include a lack of knowledge on the part of the student regarding: (a) AT device operation or maintenance, (b) the AT options that are available, and/or (c) the process required to receive AT. Additionally, students must be effective self-advocates in order to navigate the AT request process. Unlike elementary, middle, and high school, where the burden is often on the school to identify students requiring AT, in postsecondary institutions, it is often incumbent on the students to self-identify as having a disability and request specific AT solutions (Parker and Banerjee 2007). The point of contact for students with disabilities is usually the office of disability services. In the United States, this office has the right to request third-party verification of the disability. In order to qualify as a disability requiring AT accommodations, the disability must impact the student's ability to be successful in such activities as getting to class, participating in class (e.g., taking notes, asking and answering questions), completing homework, accessing learning materials or environments, and/or taking tests. If the student lives on campus, accommodations for daily living may also be considered. After eligibility is confirmed, the disability service officer and the student discuss the impact of the specific disability on the student's education and the accommodations that may mitigate those specific needs. After specific accommodations are determined, the disability services office provides the student with a letter that details the accommodations the student is allowed to receive. This letter is then used by the student, as needed, to ensure the accommodations are met by other elements of the postsecondary institution.

In order to successfully navigate this process the student must have skills in self-advocacy. When a student with a disability enters a postsecondary institution, it is the student's responsibility to seek out the disability services office for support. According to Hadley (2011), students with disabilities must make the transition from passive dependency on the school system to "a more active and responsible role" (p. 78). To be an effective self-advocate, students must (a) have a good understanding of their disability, (b) be able to seek support from the institution, (c) know the AT equipment that works best for them and their needs, and (d) be able to convey their needs to faculty and disability service staff. One approach to helping future postsecondary students be prepared for this responsibility is to make sure that students with disabilities in high school who are planning to seek a postsecondary degree know that there are provisions for them, but that they must seek them out. Efforts to teach high school students with disabilities to identify what AT may be available at their postsecondary institution and how to obtain AT should be included when developing individualized transition plans for college-bound high school students with disabilities (Mull and Sitlington 2003). Additionally, postsecondary institutions should provide all students with information on how to complete this process as part of their incoming student orientation.

Institutional Factors that Impede AT Provision and Use

Institutional factors that inhibit obtaining AT or that lead to early abandonment of AT include: (a) limited funding that precludes purchasing sufficient AT options and/or offering training on AT operation to disability service coordinators and students, (b) negative attitudes related to the nature of a disability and/or the type of assistance provided by AT that may be held by some instructors, and (c) the manner in which AT is distributed or made available to students.

Even in countries where federal legislation requires that institutions of higher education provide AT options for students with disabilities in order to receive federal funds, funding limitations are still often a reality (e.g., Americans with Disabilities Act of 1990; Day and Edwards 1996). Fortunately, this problem may be abating over time for two reasons. First, many forms of AT are now less expensive and the decreasing cost has helped occasion an increase in the availability of AT (Day and Edwards 1996). Second, more postsecondary institutions are embracing the concept of universal design. Universal design was originally conceived in the field of architecture and involved structures being initially constructed to ensure ease of access for people with physical disabilities; for example, entrances are built with ramps, bathrooms have accessible toilets and sinks, and doors and hallways are made wide enough to accommodate wheelchairs. By initially designing structures with such features, the more expensive process of retrofitting buildings is avoided, and less supplemental AT may be needed to access environments like campus dormitory rooms and cafeterias. The concepts and values of universal design have expanded to include not only universally accessible physical structures but also approaches to instruction, design of materials (e.g., staplers, copy machines, and so on), furniture arrangement, and common classroom technologies (Edyburn 2010; King-Spears 2009). In addition to potentially reducing the need for some forms of AT, universal design when applied to learning and instruction, may reduce stigmatization caused by a disability and lessen the feelings of isolation noted by some students (Campbell 2004; King-Spears 2009; Quinlan et al. 2012).

Attitudes of postsecondary instructors (e.g., college professors) regarding various disabilities and the use of AT range from highly supportive of providing AT accommodations for a variety of educational needs to completely non-accommodating. Quinlan et al. (2012) conducted a qualitative study designed to examine the provision of accommodations for postsecondary students with disabilities. Ten university students were interviewed and their responses were systematically analyzed. Student interviews identified two ways in which instructors may discourage students from using AT. First, instructors who have rigid classroom procedures and policies may inadvertently signal to students with disabilities that they are not likely to be supportive of AT; this may occur even when nothing negative is actually said about AT, and in reality, the instructor would be accommodating. This attitude is captured in a quote by one of the participants:

> Sometimes when you meet a teacher for the first time, they go over their syllabus and say my class is going to be like this… and you must do this… Sometimes they might come off strong and you might think they are not as nice and not as understanding of individuals with learning disabilities (p.227).

This perception of a negative attitude regarding AT and/or disability, although sometimes unfounded, causes some students to be reluctant to notify instructors about the AT accommodations the disability service office has deemed appropriate. Further, if this attitude is encountered early in the student's postsecondary experience, it may dissuade them from seeking services and accommodations that would be beneficial in the first place (Garrison-Wade 2012; Harpur and Loudons 2011). The solution in such cases may be as simple as requiring that the university's policies and procedures related to AT be included in each syllabus. The second manner in which instructors inhibit AT use is more direct and appears to be caused by a lack of knowledge concerning disability, legal rights, and the benefits of AT. Specifically, instructors may actively refute the student's diagnosis and deny the use of AT in their classroom. When this occurs students should seek advocacy through the office of disability services. Unfortunately, some students may experience embarrassment or feelings of shame and, as a result, may simply attempt to do without the needed AT, potentially causing detriment to their education.

The manner in which some forms of AT are made accessible to students may also be a barrier for some students. Postsecondary institutions often use one of two delivery models for AT services. First, they may use a distributive location model, in which the student with a disability can transport the AT device or service anywhere it is needed. This delivery model is typically used for AT that is easily portable and is required across environments (e.g., screen reader software installed on the student's laptop). The second model involves keeping the AT device in a central location on campus. This model is typically used for AT that is either too large to be easily transported or too expensive to allocate to an individual student (e.g., large copy machine size scanners). The central location model may be able to deliver more consistent and efficient services compared to the distributive model but has been criticized for creating a stigma and/or inconvenience. For example, a typically developing student has many options for places to study, but a student who requires a screen reader to study is only able to study in the library if the screen reading device is permanently located there. Therefore, the distributive model often represents a more inclusive approach because it promotes integration of students with disabilities into the mainstream student body. Many postsecondary institutions in both the United States (Burgstahler 2003) and Canada (Abreu-Ellis and Ellis 2006) support and endorse the use of a distributive model for AT services.

AT Device Characteristics that Impede Use

Finally, the characteristics and features of the AT device itself may influence whether or not a student chooses to request the device and/or continues to use the device. For example, AT devices may require specific skills to setup (e.g., computer skills required to install AT software to a laptop), operate, and/or maintain (e.g., Parker and Banerjee 2007). Students lacking these skills that are attending institutions that do not offer training on AT use may decide not to bother or may abandon the device due to frustration or feelings of incompetence (Alper and Raharinirina 2006; Day and Edwards 1996; Goodman et al. 2002). Effort should be made to ensure that there is alignment between the needs and skills of the student and the AT device selected. This should include consideration of more than merely the student's area of disability and the function of the AT device. The AT selection process should also include consideration of the student's ability to operate the device and the device's size, weight, and appearance. Further, devices that require little or no maintenance (e.g., software updates or preventive mechanical maintenance) should be given preference over devices that do.

Conclusions

This chapter reviewed and summarized research related to: (a) the types of AT options available to postsecondary students with disabilities, (b) intervention research aimed at determining the potential benefits of AT for this population, and (c) reasons why seemingly beneficial AT may not be sought or may be abandoned prematurely. Overall, there appears to be a wide range of AT options available (see Table 3.1). Unfortunately, the majority of these options have not been evaluated in intervention research, and the effects of AT provision on educational outcomes for postsecondary students with myriad disabilities cannot yet be ascertained with certainty (Chambless and Hollon 1998).

Although it may seem obvious that AT would be beneficial, researchers investigating this area have reached different conclusions. For example, Webb et al. (2008) found that AT is one of the five critical needs of postsecondary students with disabilities and concluded the use of AT is essential for many students that would not otherwise be able to access postsecondary educational environments and participate actively and successfully in the classrooms, coursework, and testing. Conversely, O'Neill et al. (2011) found that the use of AT by college students actually decreased the odds of the student graduating and offered some possible explanations for that finding that are consistent with the conclusions from this review. First, they suggested that postsecondary institutions may not provide enough individual attention to students, thereby limiting their ability to access available technology or to switch AT devices should the need arise. Second, the authors suggest a lack of funding may prevent postsecondary institutions from having the most up-to-date and effective technology available. Another possibility, typically related to funding limitations, is that postsecondary institutions may not provide appropriate or adequate training to students on the use of the AT that is available. Finally, because students with more significant disabilities may be those most likely to qualify for AT, additional obstacles related to disability severity may contribute to low graduation rates of these students.

Ultimately, the findings of the review presented in this chapter support findings of similar reviews. Specifically, many AT options exist, more intervention research is needed, and AT alone may not be enough in all cases. If students with disabilities in postsecondary institutions are not provided with: (a) the right AT matched to their needs, preferences, and skills, (b) training in how to use the equipment, device, or software correctly, and (c) provided a range of options that may be effective, they may not be as successful as they could be.

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Chapter 4
Assistive Technology for People with Communication Disorders

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Introduction

Communication involves message exchange, i.e., sending and receiving messages (Schindler et al. 2010). A simple example is when one person (the speaker) asks another (the listener) to *pass the salt*. To be successful, the speaker must have effective and efficient ways of sending messages. Because communication is a reciprocal process, the listener must also play a vital role in the communication process by (a) recognizing that a message has been sent, (b) interpreting the meaning of that message, and then (c) acting upon (responding to) the sent message. As Schlosser and colleagues noted, successful communication (or message exchange) depends on the concept of shared meaning between speaker and listener (Schlosser et al. 2007a). A spoken request for salt, for example, is only likely to be

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effective if the listener hears and understands the speaker's request. While spoken language is perhaps the most obvious means of sending a message—and hearing speech is perhaps the most common mode for receiving spoken messages—successful communication can also occur within non-spoken and nonauditory communication modes (Skinner 1957), such as through the use of sign language, gestures, or writing. Communication can also occur through the use of some type of assistive communication technology, such as an electronic speech-generating device (SGD; Wendt et al. 2011).

While Schindler et al. (2010) acknowledged that message exchange is an incomplete definition of communication, the sending and receiving of messages captures a fundamental aspect of the complex process of communication. In line with this conceptualization of communication, the overall aim of this chapter is to review research that has evaluated the use of assistive communication technologies to improve message exchange in persons with specific types of communication disorders. The main focus of our review is on studies that have aimed to teach individuals with communication disorders to use assistive technology for sending messages. In addition, studies comparing the use of such technology under different environmental conditions were also considered relevant, as were studies in which assistive communication technologies were directed at the receptive language domain, that is receiving messages.

If communication involves sending and receiving messages, then communication disorders can be viewed as involving an impairment with respect to the sending and/or receiving of messages (Schindler et al. 2010, p. 167). Impairment with respect to the sending and/or receiving of messages can result from a variety of conditions, such as aphasia, autism, cerebral palsy, dysarthria, intellectual disability, and severe/multiple disabilities. Several of these conditions are covered in separate chapters of this book. To avoid overlap, the present chapter focuses on studies that evaluated the use of assistive technology to address the communication needs of individuals with disorders not covered in other chapters.

It is important to note that the nature and severity of communication impairment can vary widely across individuals with the same condition. For example, some cases of dysarthria (i.e., problems in articulating speech) are more severe than others (Duffy 2005). Individuals with mild dysarthria, for example, are generally able to use speech for communicating, whereas people with severely dysarthric speech are less likely to be able to successfully transmit messages effectively via the speech mode. Generally, assistive communication technology is indicated for individuals with communication disorders that are more severe and thus more likely to significantly interfere with the ability to send and/or receive spoken messages.

Disorders can arise in relation to various aspects of communication, including (a) voice, (b) speech, (c) language, and (d) hearing (Schindler et al. 2010). Several more specific problems are associated with each of these aspects of communicative functioning. For example, voice disorders can affect voice timing, pitch, and volume; whereas speech functioning may be impaired in terms of fluency (stuttering) and articulation (Duffy 2005; Schindler et al. 2010). In addition to affecting one or more communicative functions, impairments can manifest in one or more of the major language subsystems; that is, phonology, morphology, syntax, semantics, and/or pragmatics (Schlosser et al. 2007a). For example, children with phonological disorder use significantly fewer speech sounds than peers and thus do not pronounce some words correctly. When the phonological disorder is severe it can prevent successful message exchange, especially with unfamiliar listeners (Gierut and Morrisette 2011). Children with developmental disorders, such as intellectual disability or autism spectrum disorders (see Chap. 6) also often make persistent morphological errors when speaking, such as *When will the party began?* or *I putted my shoes on*. These problems may have some relation to the relatively high cognitive demands associated with these features of grammar (Acarlar and Johnston 2011). Communication disorders can also affect one or more of the three major domains of communication; that is, the expressive, receptive, and/or written communication domains (Schlosser et al. 2007a).

Communication Intervention and Assistive Technology

Communication intervention research aims to develop new and more effective approaches for addressing this myriad of communication disorders. When the effectiveness of an intervention approach or technique has been supported by a good number of high-quality studies, then that approach can be considered evidence based or empirically supported (Horner et al. 2005; Schlosser and Sigafoos 2008). In line with contemporary evidence-based practice (Schlosser and Sigafoos 2009), there is growing consensus that the assessment and treatment of communication disorders should be based on the best available evidence of what works, along with relevant stakeholder perspectives and clinical expertise (Schlosser and Raghavendra 2004). That is, clinicians should aim to use only empirically supported assessment and intervention approaches. Dollaghan (2007) argued that use of the best available evidence helps clinicians reduce the uncertainty associated with designing treatments for communication disorders.

Adopting an evidence-based approach in communication intervention requires critical appraisal of the available research evidence (Schlosser et al. 2007b). The appraisal process is intended to determine whether there is sufficient high-quality evidence to support the use of a specific treatment for a given situation. For example, a clinician would want to know whether there is sufficient evidence to support the use of assistive technology for improving communicative functioning in individuals with specific types of communication disorder. Along these lines, this chapter provides an overview and appraisal of studies that have evaluated the use of assistive technology in the treatment of several common types of communication disorders.

The present overview of assistive technology interventions for communication disorders is timely because of three major trends in the field. First, there has been rapid development of new types of technologies (Wendt et al. 2011). Many of these new and emerging technologies have potential applications in the treatment of communication disorders. Indeed, there is considerable overlap with respect to the use of assistive technologies and the field of augmentative and alternative communication (AAC) for persons with communication disorders, as noted by Wendt et al. (2011). For example, iPads and related devices have been successfully used as SGDs for individuals with developmental disabilities who have limited or no speech (Kagohara et al. 2013).

Second, there is increasing attention being devoted to clinical issues surrounding the use of these rapidly developing assistive technologies in the treatment of communication disorders (Hill and Corsi 2012; Teachman and Tam 2011; Wendt et al. 2011). Hill and Corsi, for example, highlighted the growing role of assistive technology in the treatment of a wide range of communication disorders and the corresponding need for clinicians to gain competence in the use of assistive communication technology. Similarly, Teachman and Tam delineated a number of important aspects of communication functioning that should be addressed when considering the use of assistive technology for children with communication disorders. These aspects include the extent to which the assistive technology promotes (a) social engagement, (b) literacy, and (c) participation across a wide range of environments.

Third, there appears to be an increasing amount of research into the use of assistive technology for people with communication disorders, but reviews of this research literature have been limited. For example, Sutherland et al. (2010) reviewed 11 studies that used assistive technology within communication intervention programs for adults with intellectual disabilities. The assistive technology used consisted of nine different types of SGDs. Sutherland et al. (2010) defined SGDs as “any switch-operated, electronic, or computer-based communication aid that produces either digitized (i.e., recorded) or synthesized speech output” (p. 162). To illustrate this type of assistive communication technology, Fig. 4.1 is a photograph of a common SGD. This SGD (Tech/Talk by Advanced Multimedia Devices, Inc., Farmingdale, New York) has eight panels and six different levels for a total capacity of 48 symbols, each of which can be associated with up to 20 s of digitized speech output.

In the 11 studies reviewed by Sutherland et al. (2010), which involved 15 total participants, SGDs were most often used as an alternative to speech, which was absent or severely impaired in most of the participants. In most cases, participants were taught to use the SGD for basic expressive communication, such as requesting access to preferred stimuli and responding to questions. The results of

Fig. 4.1 Tech/Talk SGD. The Tech/Talk holds overlays of eight symbols/panels and has six different levels giving it a capacity for up to 48 digitized (recorded) messages. The Tech/Talk is produced by Advanced Multimedia Devices, Inc., Farmingdale, New York. Image used with permission

these 11 studies were generally positive in that most participants learned to use the SGD for performing the targeted communication skills. However, the review is limited in that it considered only adults with intellectual disability and one type of assistive communication technology (i.e., SGDs).

In another review, Lancioni et al. (2013, Chap. 3) summarized 54 studies that evaluated the use of SGDs in communication interventions for individuals with severe/profound and multiple disabilities. Again the SGDs were primarily intended as an alternative to speech, which was generally absent among the 149 participants across these 54 studies. The aims of the interventions applied in these studies were to teach participants to use SGDs to (a) request access to preferred stimuli (23 studies), (b) reject non-preferred objects (3 studies), (c) recruit social interaction/ initiate conversation (22 studies), and (d) reduce problem behavior by teaching SGD use (6 studies). Thus, these intervention studies could be seen as targeting severe expressive speech disorders associated with severe/profound and multiple disabilities. The results of this collective set of 54 studies were generally positive, suggesting that a range of useful SGD-based communication skills can be successfully taught to individuals with severe/profound and multiple disabilities. While this is an important overall finding, the review is again limited to the evaluation of only one type of assistive communication technology (i.e., SGDs), a low incidence population, and a rather limited range of intervention objectives.

Two related reviews, covering the use of SGDs for individuals with developmental disabilities (Rispoli et al. 2010) and children with autism (van der Meer and Rispoli 2010), reported similar findings to the reviews of Lancioni et al. (2013) and Sutherland et al. (2010). Specifically, Rispoli et al. reviewed 35 studies providing SGD intervention to a total of 86 participants, most of whom (70 %) were diagnosed with intellectual disability. Seventeen different SGDs were used across the studies, with the most commonly used type of device being single-switch or microswitch setups (46 % of studies). Participants were mainly taught to use SGDs for requesting functions (58 % of participants), with fewer participants taught to label objects (4 % of participants), answer questions (2 % of participants), or engage in multiple communicative functions (2 % of participants). On the positive side, intervention was considered successful (i.e., the participants learned to use the SGD for the targeted communicative function) in 86 % of the studies. The authors concluded that these largely positive results showed the promise of SGD technology for enabling functional, albeit generally basic, message exchange among individuals with intellectual disability and severe communication impairment. van der Meer and Rispoli (2010) reported similar trends and findings in their review of 23 studies in which SGD intervention was provided to 51 children (3–16 years of age) with autism.

Overall, the results of these previous reviews support the use of SGDs in AAC interventions for individuals with intellectual disability, autism, and severe/profound multiple disabilities. An important issue is whether SGDs and other types of assistive communication technology have a role in the treatment of communication disorders arising from other conditions, such as cerebral palsy, aphasia, apraxia, and dysarthria.

In an attempt to advance these current trends and build on existing reviews, we next provide an overview and appraisal of studies that have evaluated the use of assistive technology for addressing several common types of communication disorders. The objectives of this overview are to: (a) delineate the types of assistive technologies that have been used, (b) describe the communication areas or skills targeted for improvement via the assistive technology, (c) describe how and for whom the technology has been used, and (d) summarize the outcomes associated with the use of this assistive technology. A review of this type is expected to illustrate and inform the use of assistive communication technology in clinical practice and facilitate evidence-based practice related to the use of assistive technology in the treatment of communication disorders.

The studies reviewed herein have been divided into three groups based on the nature of the presenting communication disorder. The first group concerns studies that targeted individuals with cerebral palsy. The second group concerns studies on using assistive technology for people with other motor speech disorders, such as apraxia, dysarthria, and ALS. The third group consists of studies that evaluated the use of assistive technology for improving spoken and written language expression in people with aphasia. The final part of this chapter analyzes the overall outcomes of the three groups of studies reviewed, considers the implications of these findings for clinical practice, and highlights directions for future research.

Literature Review

Studies Involving Individuals with Cerebral Palsy

Cerebral palsy refers to a class of permanent and nonprogressive impairments that affect postural regulation and motor control (Rosenbaum et al. 2007). Cerebral palsy arises from injury to the developing brain. The injury may occur prior to or during birth or in infancy. The motor control and postural impairments associated with cerebral palsy can range from mild to severe and affect one or all four limbs. Cerebral palsy is often associated with intellectual disability, seizure disorders, and sensory impairments.

In reviewing the classification of cerebral palsy, Rosenbaum et al. (2007) highlighted the value of identifying individuals with cerebral palsy in terms of subgroups. Subgroupings have been developed based on (a) the number and pattern of limbs affected (e.g., hemiplegia, diplegia), and (b) the nature of the impairment with respect to muscle tone and movement (e.g., spastic, dyskinetic). So, for example, in spastic quadriplegia all four limbs are affected by heightened muscle rigidity (hypertonic). With dyskinetic cerebral palsy, in contrast, muscle tone varies from hypertonic to hypotonic and consequently the person has considerable difficulty with fine motor control.

Fehlings et al. (2007) noted that speech and language development is not impaired in many individuals with cerebral palsy. For others, however, there may be varying degrees of communication impairment, ranging from mild to severe articulation and fluency problems to significantly delayed language development to the complete absence of functional spoken language (Schlosser et al. 2007a). For each of these scenarios, there may be some indication for the use of assistive technology to enable more intelligible speech or functional communication via nonspeech modalities.

Table 4.1 lists 13 studies focused on evaluating assistive technology to address the communication needs of individuals with cerebral palsy (Blain et al. 2010; Chan et al. 2010; Clarke and Wilkinson 2007, 2008; Costigan and Light 2010; Hreha and Snowdon 2011; Leung and Chau 2010; Lui et al. 2012; Mathisen et al. 2009; Odom and Upthegrove 1997; Raghavendra and Oaten 2007; Schepis and Reid 1995; Schepis et al. 1996). Studies are listed in chronological order and summarized in terms of the number and ages of participants, the type of assistive technology used, and the communication areas or skills targeted for improvement. To illustrate the range of assistive technology used, and the purposes to which this range of technologies has been put, we next provide a detailed description of six studies from Table 4.1.

First, Schepis et al. (1996) provided intervention to three adults who were 23, 38, and 42 years of age. All three were diagnosed with spastic quadriplegia, did not walk, and thus required wheelchairs for mobility. The participants were also described as having profound mental retardation, although IQ scores were not

Table 4.1 Studies evaluating assistive technology to address the communication needs of individuals with cerebral palsy

Studies	Participants	Ages (years)	Assistive technology/purpose
Schepis and Reid (1995)	1	23	Mega Wolf/Request preferred stimuli, interact with staff
Schepis et al. (1996)	3	23–42	Mega Wolf, MessageMate/Request preferred stimuli
Odom and Upthegrove (1997)	1	29	Liberator™, infrared control system/ Employment-related communication
Clarke and Wilkinson (2007)	2	7, 10	Delta Talker™, Liberator™/Ask questions, use "is"
Raghavendra and Oaten (2007)	1	11	Liberator™/Spell words
Clarke and Wilkinson (2008)	2	7, 14	Delta Talker™/Ask questions, combine actions with pronouns
Mathisen et al. (2009)	1	3	Vanguard II, Unity® 84/Produce multi-symbol utterances
Blain et al. (2010)	1	20	Tongue movement microswitch/Recruit attention, operate computer
Chan et al. (2010)	1	19	Throat vibration switch, Words + IST/Write sentences with computer
Costigan and Light (2010)	1	5	DynaVox DV 4™/Select target colors from SGD display
Leung and Chau (2010)	1	7	Multi-camera tongue switch/Picture matching
Hreha and Snowdon (2011)	1	59	Tash microlight switch/Make cell phone calls
Lui et al. (2012)	2	15, 20	Throat vibration switch/Picture matching

Studies are listed in chronological/alphabetical order. Related conditions include participants who were described as having motor control impairments consistent with cerebral palsy (e.g., ataxia, spastic quadriplegia, tetraplegia, or hypotonia)

provided. The participants were reported to be able to understand simple phrases and gestures when used in context, but "lacked effective communication skills" (p. 454). Given their lack of effective communication skills, intervention aimed to teach the participants to make use of SGDs to request access to four preferred stimuli/activities (e.g., magazines, cookies, musical instruments, and going outside). Photographic symbols of preferred items were affixed to a Mega Wolf or MessageMate20 SGD (Fig. 4.2) and the devices were programmed so that touching each photograph produced a corresponding request (e.g., *I want the cookie please*). The resulting speech output was either synthesized (Mega Wolf) or digitized (MessageMate20).

Fig. 4.2 MessageMate 20. The MessageMate 20 is a single-level communication device with 20 keys and either 75 s or 150 s of total recording time. The MessageMate 20 is produced by Words + Inc., Lancaster, CA, USA

Participants received baseline, training, and post-training phases. The phases were implemented sequentially with training, and post-training phases introduced in a multiple-probe across participants design (Kennedy 2005). During baseline, the SGD was attached to the participants' wheelchair tray. The trainer used a mand-model procedure (*Show me what you would do if you wanted chocolate milk.*) to create 10 opportunities for requesting preferred items. Activation of the SGD was followed by receipt of the requested item. A second baseline phase involved assessing SGD use in the absence of the mand-model procedure. Following baseline, participants were taught to make specific requests using the mand-model procedure and time-delayed graduated guidance (i.e., waiting 15 s for a response and then using the least amount of physical guidance necessary to prompt the response if necessary). Post-training sessions were implemented once participants had reached 80 % correct across two successive training sessions. Post-training involved interspersing trained and untrained stimuli and the absence of mand-modeling and graduated guidance.

The results showed no correct requests during baseline for two of the three participants, while the fourth made correct requests for one preferred item (musical keyboard) during 2 of her 10 baseline sessions for that item. With training, correct requesting was acquired and maintained at the 60–80 % level on average for all three participants, although performance varied from 0 to 100 % correct across post-training sessions. The variability in performance across post-training sessions might reflect changes in motivation with respect to the preferred items.

The results of this study suggested that mand-modeling and graduated guidance were effective in teaching three adults with spastic quadriplegia to make functional use of SGDs for an important and common type of message exchange, that is requesting preferred stimuli from a listener (Reichle et al. 1991). The study strengths included clearly defined dependent and independent variables, excellent interobserver agreement (always 100 %), and a convincing experimental design. However, the design was compromised somewhat by the fact that post-training was introduced at the same time for two of the three participants, thereby reducing the number of staggered tiers in the multiple-probe design. Still, this is one of the first studies showing the potential for enabling adults with spastic quadriplegia and profound mental retardation to communicate via SGD technology.

Second, Clarke and Wilkinson (2007) arranged two dyads of 7- to 10-year-old children. Each dyad consisted of a child with cerebral palsy and severe communication impairment and a peer who did not have any communication impairment. The two children with severe communication impairment used SGDs (i.e., a Delta Talker™ and Liberator™, respectively). Dyads were videotaped at unstructured times and in a structured conversation (dyads were asked to discuss items they would need if stranded on an island). These videotapes were then analyzed to identify patterns in the use of the assistive communication technology. The main findings were that (a) SGDs were mainly used to respond to questions initiated by the naturally speaking peer, (b) the SGD responses tended to be relatively brief and simple messages, and (c) peers were quite responsive to the target child's SGD use.

While the Clarke and Wilkinson (2007) study did not involve an intervention per se, the findings of their video analysis suggest there may be value in ensuring the assistive communication technology is setup to enable the person to respond quickly and clearly to questions from naturally speaking peers. For example, *yes* and *no* responses should be easy to perform because these are likely to be frequently required. As Clarke and Wilkinson noted, the results also suggested there may be benefit in some instructions so that naturally speaking partners take some shared responsibility for ensuring that successful message exchange occurs for the person using assistive communication technology. This suggestion extends the view that successful communication requires shared meaning between speaker and listener (Schlosser et al. 2007a). The extension also highlights the possible need to accommodate the various nuances (as also reported by Clarke and Wilkinson 2008) in the conversational process that arise when one participant communicates via assistive technology.

Third, Raghavendra and Oaten (2007) described a case study involving an 11-year-old boy. The boy was described as having quadriplegic cerebral palsy and complex communication needs. He did not speak, but could make some vocalizations. Because of his communication impairment, he used a Liberator™ SGD for "basic social communication" (p. 301). The intervention provided by Raghavendra and Oaten (2007) focused on teaching the boy to spell three-letter words with the Liberator™. Over three baseline sessions, he performed at 25 % correct or less when asked to spell words. Intervention then began under three different feedback conditions in line with an adapted alternating treatments design (Kennedy 2005). Specifically, one set of words was taught with the SGD providing feedback in print. The second set of words was taught with feedback consisting of synthetic speech output. And the third set of words was taught with feedback consisting of both print and synthetic speech output. The boy learned to spell under each of the three feedback conditions, but learned quicker in the print-only condition. This suggest that the visual (print) feedback from the Liberator™ was a more effective form of feedback than speech output for teaching this boy to spell words. This makes sense in that spelling might be conceptualized as a more visual than auditory task. Interestingly, however, a similar study by Schlosser et al. (1998) found that

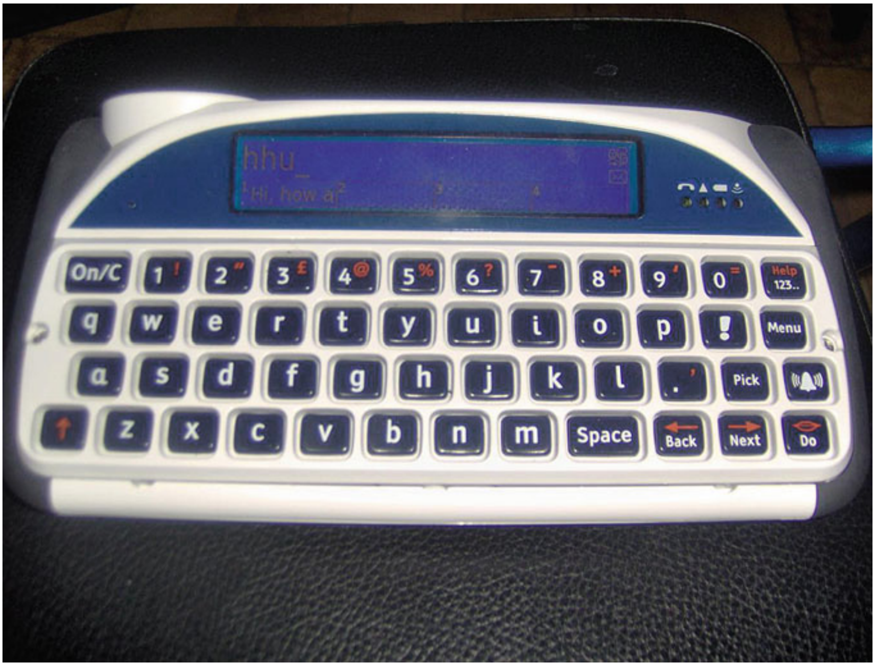

Fig. 4.3 Photograph of a LightWriter. The LightWriter is a text-to-speech SGD manufactured by Toby Churchill Limited in the United Kingdom (http://www.toby-churchill.com)

speech output from a SGD was a more effective form of feedback than print. The discrepancy between Raghavendra and Oaten (2007) and Schlosser et al. (1998) results might stem from the fact that the participant in the Schlosser et al. (1998) study was diagnosed with autism and used a different type of SGD (i.e., a Light-Writer, see Fig. 4.3). In any event, these results suggest that the type of feedback provided by the assistive technology might be an important variable in relation to the ease and speed of learning to use assistive technology.

Fourth, Mathisen et al. (2009) described an intervention involving a 3-year, 10-month-old girl with the spastic quadriplegia subtype of cerebral palsy. Her speech was estimated at the 26-month level. Prior to intervention, an assistive communication system was configured. The system consisted of the Vanguard II with 84 icons. Features of the Vanguard II include dynamic display, synthesized speech output, an activity row, and a key area size that was suited to the girl's fine motor ability. The intervention aimed to extend the child's literacy skills, including producing grammatical forms (e.g., nouns, verbs, and adjectives) and functional expression (e.g., comments, questions, and negation). Intervention occurred at home and in her preschool setting in the context of reading books. During intervention sessions, a book was read to the girl and she was asked to find and select the corresponding icons from the display of the Vanguard II. After 12 weeks of intervention, posttest results showed improvements across a range of communicative skills, such as increased syntactic complexity, increased length of messages (from single icon to five-icon messages), increased vocabulary, and better conversational turn-taking. The unique aspects of this study were the naturalistic approach to intervention and incorporation of a generative icon system with a multifeature SGD. The results suggested that this package contributed to the child's wide-ranging improvements from the pretest to the posttest 12 weeks later. However, the pre-post design cannot rule out the possible influence of extraneous variables, such as history, maturation, and practice. Maturational changes were, however, unlikely to have significantly impacted the use of the assistive technology employed by Mathisen and colleagues with this young girl.

Fifth, Chan et al. (2010) evaluated a vocal cord vibration switch as a means of enabling a 19-year-old man to access a computer. The man's physical condition and developmental history was consistent with a diagnosis of hypotonic cerebral palsy. He required a wheelchair for mobility, had only minimal control of his upper extremities, and communicated with 1–2 word utterances that became less intelligible with fatigue. As a result, he relied on AAC for communication, including an alphabet board and a voice-activated switch for operating a virtual keyboard (WiViK®). Because of the fatigue issue, a new switch was indicated for enabling the man to access his computer. The new switch was described as a throat vibration switch that detected minimal throat movement rather than being voice activated.

The utility of this new switch was compared with a voice-activated switch (Words + IST) in the context of a sentence writing task. Data were collected on the time required to complete tasks with each switch and frequency of errors. The participant also rated the exertion/difficulty level for using each switch. In addition to the sentence writing task, the man used the new throat vibration switch for a 2-month trial and rated his satisfaction level with the new switch.

The results indicated better performance with the throat versus the voice-activated switch. In addition, the man rated the throat switch as less tiring than the voice-activated switch. After the 2-month trial, the man indicated his general satisfaction with the new switch, although he indicated that a wireless version would be preferred. Overall, the authors noted that their new throat switch was superior to a commercially available voice-activated switch in terms of "sensitivity, speed, and user-perceived level of exertion" (p. 77). The man was also more satisfied with the new switch. These results raise a number of important issues, including: (a) the value of assessing participants' subjective perceptions of different assistive communication technology options, (b) the need for introducing new technologies for participants who may experience fatigue with existing technology and/or in light of changing motor and cognitive abilities, and (c) the need for relatively long-term trials (2 months) for gauging participant satisfaction with new assistive technologies.

Sixth, Hreha and Snowdon (2011) described the case of a 59-year-old man with tetraplegia resulting in ventilator dependency, tube feeding, and minimal upper extremity movement control. An important goal for this man was to be able to make cell phone calls. The intervention challenge, therefore, was to identify a viable system for enabling the man to make effective use of a cell phone. To this end, the authors developed a system consisting of a bluetooth-enabled cell phone adapted for use via a Tash microlight switch (http://www.ablenetinc.com, Ablenet 2003). With this switch, the cell phone could be operated with minimal thumb movements. A second critical component of the intervention was positioning the cell phone and switch on the wheelchair armrest to ensure easy access and switch operation. With this adapted set up, the man initially showed 50 % accuracy in making calls, but with 4 weeks of occupational therapy, his performance increased to 100 %. While this case report did not include experimental controls, the results are highly suggestive that the setup and therapy were helpful in promoting more independent cell phone use. Given the ubiquity of cell phones, achieving independence in this skill is likely to be an important therapeutic goal for many individuals with communication disorders.

Studies Involving Individuals with Motor Speech Disorders

Impairment of motor control can lead to a number of speech/communication disorders. For example, apraxia is identified as a muscular control problem that impairs fluent execution of voluntary movements, including the oral motor movements required for speech (Love 1992). When impairment with respect to motor control of speech production occurs in early childhood, a diagnosis of developmental apraxia of speech (DAS) may be given (Bornman et al. 2001). As Bornman et al. noted, DAS is characterized by (a) impaired ability to imitate speech, (b) slower production and initiation of speech, (c) vowel, fricative, and sound sequencing errors, and (d) delayed expressive language development (p. 623). Assistive communication technology may have a role in cases of severe apraxia and DAS to supplement the person's natural speech, thereby enabling more effective communication (Cumley and Swanson 1999).

Dysarthria, in contrast, refers to disruption of muscular control that affects speech intelligibility (Parker et al. 2006). In severe cases dysarthric speech can be "completely unintelligible to the unfamiliar listener" (Parker et al. 2006, p. 149). In such cases, assistive communication technology might be aimed at enabling the person to produce digitized or synthetic speech output that might be more intelligible than the person's natural speech.

Another condition affecting motor control, including oral motor control, is amyotropic lateral sclerosis (ALS). ALS is a progressive neurological disease that causes muscle atrophy, spasticity, and breathing problems (Ahmed and Wicklund 2011). ALS is often associated with severe dysarthria or anarthria (i.e., loss of motor ability required for speech). Given their propensity for dysarthria or anarthria, assistive communication technology may be indicated for people with ALS. However, the development of appropriate assistive communication technology for persons with ALS is complicated by the fact that the motor abilities of such persons are likely to worsen progressively over time. Hence, there is often the need to reconfigure the assistive technology and develop new access modalities that can be activated with minimal (worsening) motor movements.

Table 4.2 lists 10 studies that have focused on the use of assistive communication technology for persons with DAS, dysarthria, and ALS (Azuma et al. 2010; Bornman et al. 2001; Cumley and Swanson 1999; Ferm et al. 2010; Hageman et al. 2008; Hawley et al. 2007; Laffont et al. 2007; Lancioni et al. 2012a, b; Parker et al. 2006). These studies are summarized in terms of the number of participants, participant ages, type of assistive technology used, and the communication areas or skills that were targeted for improvement/intervention (Table 4.2). Six studies from Table 4.2 are reviewed in detail to illustrate how the assistive technology has been used to support individuals with DAS, dysarthric speech, and ALS.

First, Cumley and Swanson (1999) presented three case studies, each involving AAC intervention for a child with DAS-like symptoms. The first case involved a 3-year-old child with 1q syndrome and limited speech intelligibility. AAC intervention included the use of a WOLF device (ADAMLAB, Troy, MI, USA). Intervention aimed to support conversational interaction. The WOLF is a portable SGD with synthesized speech output and touch-sensitive keys. For this study, the keys were configured with black and white line drawings representing single words. AAC intervention consisted of expanding on the child's use of the SGD while simultaneously saying the corresponding word. For example, if the child selected the drawing for *BALL* from the SGD, the clinician would expand this by touching two symbols (e.g., *THROW BALL*) while also saying *throw ball*. After

Table 4.2 Studies evaluating assistive technology to address the communication needs of individuals with Apraxia, ALS, and Dysarthria

Studies	Participants	Ages (years)	Assistive technology/purpose
Cumley and Swanson (1999)	3	2–3	Wolf SGD, Sharp Memo Writer/Social and functional communication
Bornman et al. (2001)	1	6	Macaw SGD/Answer questions
Parker et al. (2006)	8	Adults	Computer speech recognition/Single word intelligibility
Hawley et al. (2007)	8	Not specified	Computer speech recognition/Speech intelligibility
Laffont et al. (2007)	10	9–66 ($M = 32$)	Dialo® speech synthesizer/Speed of keyboard communication
Hageman et al. (2008)	1	49	SGD/Increase intelligibility of words and phrases
Azuma et al. (2010)	3	39–52	Computers and SGDs/Picture naming
Ferm et al. (2010)	5	51–71	Talking Mats/Conversation
Lancioni et al. (2012a)	1	51	Optic microswitch/Write requests, make choices
Lancioni et al. (2012b)	2	51, 66	Optic microswitch/Makes requests, write and send text messages

6 months of AAC intervention, the authors reported an increase in the child's mean length of utterance (MLU) from 2.6 to 4.6. This finding suggested that the SGD was effective in supporting expressive language development, but because the study involved a pre-post design, maturational effects might also have influenced the child's MLU scores over the 6-month period.

The second case involved a 2-year-old girl with limited vocalizations. AAC intervention involved teaching the child to use a communication board when her communicative partners did not understand her attempts to communicate using natural speech. Intervention procedures included verbal reinforcement for using the communication board to supplement natural speech and to repair communication breakdowns when her natural speech attempts were not successful. Later, she also used a WOLF SGD. The authors reported that the AAC devices and procedures helped to support the child's natural speech and enabled her to repair communicative breakdowns. However, the study is limited as objective measures of progress were not provided nor was there adequate control of possible extraneous variables (e.g., maturation and practice effects).

AAC intervention for the third case (a 3-year-old boy with symptoms of DAS) involved the provision of communication boards and a Sharp Memo Writer (Sharp Electronic Corporation, Mahwah, NJ, USA). The boards were intended to support his natural speech during conversation and when requesting objects. Age-appropriate phrases were programmed into the Sharp Memo Writer to support his conversational interactions with peers. He also received intervention to use his AAC options in the community (e.g., asking for assistance in a grocery store). The reported results included increased interactions with peers, greater communication independence, and increased communication initiation. However, as with the second case, experimental controls and objective data were lacking.

Second, Bornman et al. (2001) described the use of a digital SGD with a 6-year-old boy. The boy's developmental history and symptoms were suggestive of DAS (i.e., delayed language development and articulation problems). Over a 30-month period, he had made little progress with traditional treatments for DAS and was, therefore, provided with a SGD (The Macaw, produced by Zygo-USA, Fremont, CA, USA). The Macaw produces digitized speech output and was configured with an overlay of 12 picture symbols that could be used to produce digitized speech output. In this study, the digitized speech output was intended to function as a means for the boy to initiate conversations related to story books (e.g., *What is his name?*). The child received two baseline sessions to assess his use of the SGD during a story book reading activity with his mother and with two different stories. Intervention consisted of two, 1-hour training sessions during which the child practiced using the SGD to initiate conversations about the stories. Training occurred with two new stories. After training, baseline conditions were repeated with the first two stories and later with a new untrained story. The results showed an increase in verbalizations, gesture-based communication, and use of the SGD from baseline to post-training. Comprehension, application, and synthesis also increased post-training, whereas knowledge and the frequency of asking questions did not. These results suggest that the SGD-based technology and the intervention procedures facilitated certain aspects of communication, but replication with other children with DAS would be important to verify the generality of such effects. Still, the study demonstrates a potentially useful way to apply assistive communication technology in what would seem to be an ecologically valid and highly practical context for intervention (i.e., reading story books).

Third, Parker et al. (2006) focused on evaluating computer-based speech recognition technology for eight adults with severe dysarthric speech. The speech recognition technology was calibrated in the context of several environmental control tasks (e.g., turning on a radio or lamp by saying *radio* or *lamp*). The study involved a self-training component (speaker prompted to produce a word) and development of acoustic models to identify the speaker's most typical production for each word. The results showed increasing consistency in articulation for six of the eight participants and faster times in completing the environmental control tasks over a period of 4 weeks. The results suggest that computer-based speech recognition technology has the potential to transform unintelligible dysarthric speech into a successful response mode for environmental control.

Fourth, Laffont et al. (2007) examined patterns of use and satisfaction with using speech synthesis technology in 10 individuals with severe dysarthia. These 10 individuals ranged from 9 to 66 years of age ($M = 32$ years). The assistive technology was The Dialo® device, developed in 2001 by the Proteor Company in Dijon, France. Words are entered into the unit by typing on a keyboard or through single-switch scanning. In this study, when a letter was entered, the device listed five full word options (i.e., word prediction). Once entered, words were then produced in synthetic speech. Initially, participants received 10 h of training (1 h per day for 10 days) on how to use the Dialo® speech synthesizer unit. They then took the device home and used it for 2 months. Data on participants' level of use of the device were collected via special software incorporated into the device. Level of use data included total number of keystrokes and use of word prediction function. Satisfaction with the device was collected via participant ratings on a questionnaire. Total number of keystrokes during the 2-month trial varied from approximately 10,000 (Participant 1) to 75,000 (Participant 10) with a mean of approximately 16,000. Similar variability was noted with respect to the number of times word prediction was used (range approximately 50–2250; mean approximately 300). These objective data suggested that the 10 h of training enabled most participants to make regular and consistent use of the device to compose messages. Satisfaction ratings, which were overall found to be *very good*, suggested participants were favorably disposed to using the device. This high level of satisfaction most likely accounts for its regular and consistent use over the 2-month trial. This study points to three important factors that may contribute to continued use of assistive communication technology: (a) an initial period of training to ensure participants are able to use the technology, (b) a prolonged trial period in natural environments, and (c) a high level of satisfaction with the technology.

Fifth, Lancioni et al. (2012a) described a technology-aided program to enable better communication interaction and more independent leisure engagement in a 51-year-old man with ALS, diagnosed 3.5 years earlier. He was described as having anarthia and limited ability to move his body, although he could tilt his head, move his eyes, and blink. The technology set up for him consisted of a laptop computer with Clicker 5 software (Crick House, Moulton Park, Northampton, UK). The computer and software was accessed via an optic microswitch activated by a slight tilt of the head. The software program included an initial screen with four classes of events that the man could choose via the microswitch: (a) songs, (b) video, (c) keyboard emulator for writing messages, and (d) reading. When the song or video category was selected, a second screen appeared with a menu of specific songs or videos. When the keyboard category was selected, a keyboard emulator was displayed enabling the man to write message via the microswitch. The Read category was then used to produce (via the computer) any messages written via the keyboard. The study involved an ABAB reversal design (Kennedy 2005). During baseline, the new technology was not available. Instead the man could use his existing eye-gaze communication board. Intervention phases involved the provision of the new technology, which was introduced with three practice sessions. The results showed that the frequency of communication (i.e., words written per session, requests made) and leisure engagement (listening to songs, watching videos) was greater during the intervention sessions with the new technology than in the baseline sessions with the eye-gaze communication board. The results are important in showing that presenting new and more technologically advanced AAC options might promote greater levels of communication even among people who have an existing (low-tech) communication system. The findings reported by Lancioni et al. 2012a could have been due to several factors, such as (a) novelty effect, (b) less effort, (c) more flexibility, and/or (d) creation of a communication system that was more relevant to the person's present situation.

Sixth, Lancioni et al. (2012b) reported on the development and evaluation of a novel optic microswitch arrangement for two adults with ALS. Their evaluation was presented as two controlled case studies. The first case study involved a 51-year-old man with ALS. The man was described as anarthric and with minimal motor control. Specifically, the man could perform "slight lateral tilt[ing] of his head, eye gazing, and eye blinking" (p. 1606). The new technology program consisted of two computer systems for (a) sending text messages, and (b) engaging in Skype conversations. The systems were operated via an optic microswitch interface, which was activated by a slight tilt of the head. The man received two types of sessions. During text messaging sessions, software was loaded onto the computer systems that enabled the man to send and read text messages via microswitch activations. For videophone conversational sessions, links could be selected via microswitch activations to connect the man to his [adult] children's Skype addresses. The study consisted of baseline and intervention phases with the introduction of intervention sessions staggered across the text messaging and videophone conditions in line with a multiple baseline design (Kennedy 2005). Intervention involved providing the new technology systems and guiding the man to use the system during two initial practice sessions. With this intervention, the frequency of texting and Skyping increased, as did the amount of time engaged in text- and Skype-based communication.

In the second case, a 66-year-old man with ALS was provided with the optic microswitch and computer systems that were setup to (a) access and request preferred leisure stimuli (e.g., videos, songs), and (b) send and read text messages. Intervention, similar to that provided to the first man, was introduced across the two types of sessions (leisure requests and text messaging) in accordance with a multiple baseline design. The results showed increased microswitch activations with the onset of intervention.

Overall the results from these two case studies reported by Lancioni et al. (2012b) demonstrated that the two men successfully used the novel optic microswitches for relatively advanced communication (e.g., texting and making Skype calls) and with relatively little intervention effort. This is an important finding given that people with ALS may lose the ability to use more typical responses (e.g., directly pressing keys on a computer keyboard) and thus they may have to rely on minimal motor movements, such as a head tilt response. Novel microswitch solutions—such as the optic microswitches used with these two men—may enable persons with deteriorating motor control to make use of the latest communication technologies (e.g., text messaging and Skype) and thus remain socially connected to friends and family.

Studies Involving Individuals with Aphasia

This section covers the third group of studies, which evaluated the use of assistive communication technology in the treatment of aphasia. The term aphasia refers to a class of communication impairments stemming from damage to language centers of the brain (Schlosser et al. 2007a). The damage may occur suddenly—as in the cases of stroke or head injury—or develop gradually in relation to an infection, brain tumor, or dementia.

Aphasia is characterized by impairment in the expression of speech and the understanding of language. Reading and writing can also often be impaired. For example, with respect to speech, the person may be only able to speak in very short or incomplete sentences. Aphasic speech also often includes unrecognizable words and the person's written messages may be nonsensical. In terms of receptive language, the person may show considerable difficulty with respect to understanding speech and be prone to overly literal interpretation of language. Goldberg et al. (2012) argued that the "Inability to access fluent and accurate speech…" is perhaps the most profound effect of aphasia (p. 222).

Aphasia is a heterogeneous and often chronic condition (Hough and Johnson 2009). Thus, symptom severity varies across individuals and over time. Several aphasic subtypes have been identified. Primary progressive aphasia, for example, is associated with degenerative conditions (e.g., dementia) and is generally noted for its "gradual progression and prolonged course" (Pattee et al. 2006, p. 151). Nonfluent aphasia, in contrast, is distinguished by "sparse verbal output and impaired word-finding skills" (Hough and Johnson 2009, p. 965). Researchers have also referred to chronic, acquired, fluent, nonfluent, and conduction aphasia (Estes and Bloom 2011). Although different terms have been used and various subtypes delineated, the communication impairments associated with aphasia all generally have a significantly negative impact on the ability to function effectively as both a speaker and listener.

Given the communication problems associated with aphasia, there would seem to be considerable potential for the use of assistive communication technology in the treatment of this condition. However, van de Sandt-Koenderman (2004) noted that the application of assistive communication technology in aphasia therapy has been rather limited and slow to develop. An important question then is what assistive communication technologies have an evidence base to support their use in the treatment of aphasia?

Table 4.3 lists 14 studies that have focused on evaluating assistive technology for addressing the communication difficulties experienced by individuals with aphasia (Behrns et al. 2009; Bruce et al. 2003; Estes and Bloom 2011; Fink et al. 2002; Hough and Johnson 2009; Jokel et al. 2009; Katz and Wertz 1997; Linebarger et al. 2001, 2007; Mortley et al. 2001; Pattee et al. 2006; Raymer et al. 2006; van de Sandt-Koenderman et al. 2007a, b). These studies are summarized in Table 4.3 in terms of the number and ages of participants, the type of assistive technology used, and the types of communication problems that were addressed by the assistive technology. We next describe six of these studies in detail to illustrate the range of assistive technologies and associated intervention procedures that have been developed and evaluated for enhancing the communication functioning of individuals with aphasia.

First, Bruce et al. (2003) explored the extent to which a man with fluent aphasia could learn to use an assistive technology system to write messages. The 57-year-old man was described as having “fluent, mild-to-moderate aphasia” (Bruce et al. 2003, p. 134) secondary to a stroke. His speech was assessed as being good, except for difficulty in producing complex messages, but his writing skills were described as “extremely limited,” as evidenced by an extremely slow writing rate, omission of verbs and function words, and lack of grammatical structure. In pursuit of the main therapy goal (i.e., to use writing for communication), the authors developed a technology-based treatment program. The software used was the Dragon NaturallySpeaking® program (version 4.01). This program was used with an Intel® Pentium® III processor. Dragon NaturallySpeaking® is a type of voice recognition software that enables one to control a computer (for typing messages for example) via speech. For treatment, the man received 17 h of training over 8 months on use of the Dragon NaturallySpeaking® program. Training was provided on a range of writing-related tasks, including dictation, editing, formatting, correcting errors, and generation of novel sentences. The results were encouraging in several respects. First, the voice recognition software correctly recognized the man’s spoken words with 84 % accuracy. Second, the man was more successful in dictating messages with the system. Finally, the time required to write messages was faster when using Dragon NaturallySpeaking®. These reported gains need to be tempered by the fact that the study involved pre-post testing, rather than a more

Table 4.3 Studies evaluating assistive technology to address the communication needs of individuals with Aphasia

Studies	Participants	Ages (years)	Assistive technology/purpose
Katz and Wertz (1997)	55	48–83	(M = 61.1)
Computer reading software/ Matching, comprehension			
Linebarger et al. (2001)	5	20–66	(M = 45.6)
Computer speech recognition, SGD/ Describe pictures			
Mortley et al. (2001)	1	67	Computer with INTACT software/ Spell words
Fink et al. (2002)	6	54–64	(M = 60.5)
MossTalk Words®/Name pictures			
Bruce et al. (2003)	1	57	Dragon NaturallySpeaking®/Read aloud
Pattee et al. (2006)	1	57	LightWriter/Describe activities shown in photographs
Raymer et al. (2006)	5	51–82	(M = 70.8)
MossTalk Words®/Word-picture matching			
Linebarger et al. (2007)	6	36–62	(M = 49.8)
SentenceShaper/Retell stories seen in video			
van de Sandt-Koenderman et al. (2007a)	34	3–82	(M = 61)
TouchSpeak/Functional use of TouchSpeak			
van de Sandt-Koenderman et al. (2007b)	30	33–82	(M = 60.9)
TouchSpeak/Functional use of TouchSpeak			
Behrns et al. (2009)	3	53–59	Computer writing aids/Write notes in personal diary
Hough and Johnson (2009)	1	56	Dialect, Speaking Dynamically Pro/ Functional communication
Jokel et al. (2009)	2	58, 75	MossTalk Words®/Name pictures
Estes and Bloom (2011)	1	65	Dragon NaturallySpeaking®/ Functional writing

rigorous experimental design. Despite this design limitation, the authors' general conclusion—that voice recognition software can be a valuable type of assistive writing technology—would seem defensible. Overall, voice recognition technology would seem best suited to individuals with impaired writing, but relatively intact speech, although voice recognition software can also be "trained" to recognize even highly unintelligible speech (Hawley et al. 2007; Parker et al. 2006).

Second, Pattee et al. (2006) worked with a 57-year-old woman with primary progressive aphasia. Her speech was only 20 % intelligible due to articulation errors and deletions of sounds, syllables, and word parts. For her treatment, the woman was asked to describe photographs of everyday activities. Her performance was compared when she used American Sign Language versus a text-to-speech device (LightWriter). Prior to treatment, two baseline sessions were conducted. Next, the woman received training with the two communication modes in an alternating treatments design (Kennedy 2005). Training involved verbal instruction and response modeling. The dependent variables were the number of words produced in describing the photographs and the number and percentage of correct descriptions. The results showed an increase in these dependent variables from baseline to post-training with both communication modes. For example, with respect to the percentage of correct descriptions, her performance with American Sign Language (LightWriter) was 42 % (91 %) in baseline and 66 % (93 %) after training. Thus the increase was more pronounced with American Sign Language. This larger magnitude of increase with the sign mode could reflect the fact that the woman's baseline performance was much lower with this mode compared to her baseline performances with the LightWriter. Thus, there was more room for improvement with the sign language mode. Following training, the woman indicated a preference for using sign language over the LightWriter. The latter finding shows that some individuals who are considered viable candidates for assistive communication technology may prefer to use nontechnology-based communication modes, such as American Sign Language.

Third, Linebarger et al. (2007) evaluated the SentenceShaper® program as a means of enhancing the speech of six adults with nonfluent chronic aphasia. The participants had deficits in a range of speech parameters, including mean sentence length, proportion of well-formed sentences, and ratio of closed to open words. Pre-post measures were collected on the above parameters by asking participants to retell the stories they had seen in videos. Between the pre- and post-test, participants received training on use of the SentenceShaper® program. SentenceShaper® is a computer-based program with which users load, store, and replay their own voice recordings. The system also includes preloaded printed words that can be selected to produce corresponding speech output, much like a typical SGD. Training was provided until participants demonstrated the ability to use the program. They then took the system home to practice for 11–23 weeks before receiving the posttest assessment with the video story retelling task. The results from the posttest were mixed in that while there was an increase in words per minute and correct descriptions per minute, this only occurred for two of the six participants. In commenting on this study, Beck (2007) pointed out a number of issues that may explain the mixed results, including: (a) the fact that some participants were performing in line with non-impaired peers at the pretest, (b) that the exact nature and severity of the participants' condition was unclear, and (c) that the pre-post design did not rule out threats to internal validity (e.g., maturation, history, and practice). Given these limitations and the mixed results, there is a need for more research to evaluate the potential of the SentenceShaper® program in the treatment of aphasia and related communication disorders.

Fourth, van de Standt-Koenderman et al. (2007a) provided preliminary data on the efficacy of TouchSpeak software, which runs on palmtop computers. The data were generated from a trial involving 34 adults with post-stroke aphasia, all of who were reported to have severe global aphasia. The TouchSpeak program allows for a large and individualized vocabulary set to be built and stored. Vocabulary items might be represented by photographs, pictures, single words, and/or sentences. Messages are constructed by selecting one or more vocabulary items (buttons) on the computer screen. Once selected and activated, the corresponding message is produced in digitized or synthesized speech. Thus the software turns the computer into a SGD. For this trial, the researchers used a pre-post design with two treatment phases. The first treatment phase focused on teaching participants how to operate the device, including how to navigate through pages to access stored vocabulary. Training lasted 12 h over a 10-week period, during which participants were instructed to find and select vocabulary items (from a standard set of 176 items) when requested (e.g., *Find the button for coffee with milk and sugar*.). The second treatment phase also involved 12 h of instruction focused on teaching participants to access individualized vocabulary to "support everyday life communications" (p. 1703). This latter phase involved role play sessions and practice in daily life situations (e.g., shopping, using the telephone). Phase 1 treatment results were available for 32 of the 34 participants because two participants withdrew after one week. Of the 32 participants completing Phase 1, the mean number of vocabulary items learned to criteria ranged from 0 to 176 with a mean of 111. Forty-seven percent of these participants acquired the complete set of 176 items within 6 h of training. Results for Phase 2 showed successful use of from 32 to 382 ($M = 159$) individualized vocabulary. Compared to the pretest scores, the posttest results showed statistically significant (10 %) increases in communication ability based on standardized ratings of scenarios of everyday communication situations. These results suggested that with training, the participants learned to operate the TouchSpeak system on the palmtops. With the system, most participants were able to access a large vocabulary set in everyday communication situations and there was an overall increase from pretest to posttest in communication ability. Most (70 %) participants also reported satisfaction with the system, but interestingly only 2 of the 12 participants who were contacted 3 years later were still using the system. This could reflect lack of interest, transition to a different system, or lack of continued need for such a system. While the pre-post design is a limitation, a major strength of this study is that participants seemed to be able to effectively use the system across a range of everyday communication situations with relatively little training.

Fifth, Behrns et al. (2009) studied the effects of an intervention involving two computer-aided writing programs on the spelling and writing performances (e.g., percentage of words spelled correctly, length of text written, words written per minute, and percentage of successful edits) of three adults with aphasia. All three participants were described as having writing and spelling problems (e.g., frequent misspellings and limited sentence writing abilities) following stroke. The assistive technology consisted of two different types of advanced writing programs. One program offered word prediction and the other provided advanced spell checking. The study design followed a single-case ABA sequence with baseline (A) and intervention (B) phases. For both phases, participants wrote text without (baseline) or with (intervention) the assistive technology. For intervention, participants chose which type of writing aid they wanted to use and were then provided with instruction and practice opportunities with the chosen aid. Intervention was associated with increases in percentage of words spelled correctly and successful edits, but there were no consistent improvements with respect to length of text generated or words written per minute. Based on these mixed results, the authors concluded that the two computer-based writing programs appeared to offer some positive support to participants with aphasia and impaired writing ability. In commenting on this study, Kearns (2010) noted design limitations, which indicate the need to interpret the reported intervention gains with caution. Specifically, the initial baseline phase was brief with variable trends and the second baseline phase was more akin to a follow-up phase because it included only a single data point collected 10 months after intervention. Still, Kearns noted that "practice with the writing aids may have resulted in more efficient use of the writing aids" (p. 203). This, combined with the certain qualitative changes in participants' writing samples (e.g., improved sentence structure and better use of punctuation) suggested the technology did add value to the written communications produced by these participants.

Sixth, Jokel et al. (2009) evaluated the MossTalk Words® program for improving naming abilities in two adult women with nonfluent progressive aphasia. The participants were reported to have considerable word-finding problems. MossTalk Words® is a computer-based software program that was specifically designed for individuals with acquired communication disorders associated with stroke or brain injury. The software is perhaps best viewed as a computer-based therapy program in which the participant works through a number of exercises (e.g., matching words to pictures and naming pictures). In this study, participants were presented with three sets of pictures that they had failed to correctly name during baseline. Intervention consisted of exposure to the MossTalk Words® program in 1-hour sessions. Sessions involved random presentation of pictures on the computer screen with participants required to speak the correct name of the picture. Increasingly more complete cues (initial letter cue, whole word cue) were delivered if a correct response did not occur. With intervention, both participants showed improvement in picture naming and showed some generalization to a sentence production task. These data provide some evidence to support the use of the MossTalk Words® program for improving picture naming skills in participants with nonfluent progressive aphasia. However, Bourgeois (2010) highlighted the need for more research in light of the study's small sample size and relatively limited scope of the generalization task. Still, the results from the Jokel et al. (2009) study are consistent with two additional studies that have evaluated the use of the MossTalk Words® program for improving expressive labeling in participants with aphasia (Fink et al. 2002; Raymer et al. 2006).

Discussion

Overall Summary of the Characteristics of the Studies

The 37 studies reviewed in this chapter included a total of 211 participants. This total consisted of 18 individuals with cerebral palsy, 42 participants with motor speech disorders (i.e., apraxia, DAS, ALS, and dysarthria), and 151 people with aphasia. Within these three groups of studies, the specific nature and severity of the presenting communication disorders varied widely. Some participants had well-developed speech, but presented with impaired writing. Others had speech articulation problems (mainly unintelligible speech). And still others presented with no appreciable amount of expressive speech. In addition, the 211 participants in these 37 studies varied widely in terms of age and extent of cognitive impairment.

With respect to the age variation across the 37 studies, it is important to note that some studies reported only age ranges. Hence a precise mean age cannot be calculated. However, within the total of 211, participant ages ranged from 2 to 83 years with a mean of approximately 40 years. It is also important to note the large differences in the average number (and ages) of participants across the three groups of studies. Specifically, in the first group of 13 studies, involving 18 individuals with cerebral palsy, sample sizes of individual studies ranged from one to three participants and participants ranged from 3 to 59 years of age ($M = 19.5$ years). In the second group of 10 studies, involving 42 participants with motor speech disorders (i.e., apraxia/DAS, ALS, and dysarthria), sample sizes ranged from 1 to 10, participants ranged from 2 to 66 years of age, and the mean age was approximately 39 years. In the third group of 14 studies, involving 151 participants with aphasia, sample sizes ranged from 1 to 55 and participants' ages ranged from 20 to 83 years with a mean age of approximately 60 years. The studies involving younger individuals tended to come from the first and second groups (i.e., studies involving individuals with cerebral palsy or DAS), whereas the oldest individuals were those with aphasia. These age trends are understandable given that cerebral palsy and DAS are usually identified in early childhood, while post-stroke aphasia is more likely in older persons.

Similar diversity can be observed among these 37 studies with respect to the type of assistive technology employed, the purpose to which it was put, and the intervention procedures implemented in the attempt to achieve the treatment objectives. With respect to the type of assistive technology employed, there was considerable use made of SGDs to enable expressive communication. Such devices were generally used as an alternative to speech when the latter was not a viable mode of communication. As reviewed in Chap. 10, SGDs are widely used as an alternative method of communication for individuals with severe and profound intellectual and multiple disabilities. As indicated in the present chapter, SGDs have also been applied to enhance communication in individuals with communication disorders arising from other disability conditions. Indeed, SGDs were used within all three groups of studies reviewed in this chapter (e.g., Schepis and Reid

1995; Cumley and Swanson 1999; Linebarger et al. 2001). In addition, a range of SGDs were employed within each of the three groups of studies, including such varied SGDs as the Mega Wolf, DynaVox, Macaw, and Vanguard II.

In addition to SGDs, several studies evaluated the viability of speech recognition software to enable individuals with highly unintelligible speech to activate assistive communication technology, including SGDs. Studies of this type were included among the second (e.g., Hawley et al. 2007; Parker et al. 2006) and third (Linebarger et al. 2001) groups of studies. Another widely applied class of technologies involved various types of microswitch configurations, which were operated by various motor actions, such as throat vibrations (e.g., Chan et al. 2010), tongue movements (Blain et al. 2010), finger movements (e.g., Hreha and Snowdon 2011), or head tilting (Lancioni et al. 2012b). With these microswitch solutions, participants were shown to be able to engage in a number of useful communication skills that would previously have been beyond the person's capabilities, including writing sentences with a computer (Chan et al. 2010), recruiting attention (Blain et al. 2010), making cell phone or Skype calls (Hreha and Snowdon 2011; Lancioni et al. 2012a), and sending and reading text messages (Lancioni et al. 2012b).

Another widely used class of technologies consisted of specially designed software used in conjunction with computers. These included software-based programs to improve picture naming (Jokel et al. 2009), spelling (Mortley et al. 2001), and comprehension (Katz and Wertz 1997). While the number of studies along these lines was relatively small, there is likely to be increased attention to this area, given the proliferation of these types of Apps for the iPhone and iPad Touch.

The communicative skills and functions that were targeted for improvement varied across the 37 studies. The majority of studies focused on what might be viewed as enabling basic expressive communication skills, such as requesting preferred stimuli (e.g., Schepis et al. 1996), asking questions (e.g., Clarke and Wilkinson 2007), answering questions (e.g., Bornman et al. 2001), and naming pictures (e.g., Azuma et al. 2010). However, more advanced expressive communication—such as producing multi-symbol utterances (e.g., Mathisen et al. 2009), employment-related communication (e.g., Odom and Upthegrove 1997), and combining actions with pronouns (e.g., Clarke and Wilkinson 2008)—were also targeted in a sufficient number of studies to conclude that such functions can be expressed via assistive communicative technology. Several studies targeted what might be conceptualized as more academic (as opposed to more functional) language skills, such as picture matching (e.g., Leung and Chau 2010), picture naming (e.g., Fink et al. 2002), identifying colors (e.g., Costigan and Light 2010), and spelling words in a spelling test format (Raghavendra and Oaten 2007). Functional literacy skills, such as writing requests (Lancioni et al. 2012a), writing and sending text messages (Lancioni et al. 2012b), and writing personal notes in a diary (Behrns et al. 2009) were also targeted. Overall, there was an impressive breadth of communication skills and functions targeted for improvement via the assistive technology solutions that were developed and evaluated across this set of 37 studies.

In terms of the methodological quality of these 37 studies, it must be noted that a range of designs and controls were employed in an attempt to demonstrate the extent to which the intervention procedures were in fact responsible for any positive changes observed in the participants' communication skills. The designs used could be classified into two main categories. The first involved preexperimental designs, including narrative case studies, pre-post design, and reliance on participant self-reports after a period of using the technology. For example, Cumley and Swanson (1999) and Mathisen et al. (2009) relied on pre-post ratings of children's progress. While their data were suggestive of an intervention effect, the pre-post design is preexperimental and thus it does not control for extraneous variables, such as maturational effects, which could have influenced outcomes. The second class of design involved varying types and degrees of experimental controls. More confidence in the veracity of results can be made when researchers use proper experimental designs to evaluate their interventions. Lancioni et al. (2012a, b) and Schepis and Reid (1995), for example, used single-case experimental designs, which provided convincing demonstrations that the intervention procedures were in fact responsible for the positive changes in the participants' communication skills. In terms of appraising the outcomes of the studies and evaluating the success of any intervention, more weight should be given to the results of studies that employed experimental designs.

This does not mean that preexperimental studies have no role to play in advancing the development of new and more effective approaches for using assistive technology in the treatment of communication disorders. To the contrary, Fey and Finestack (2009) argued that preexperimental designs and small sample sizes are useful when the aim is to explore the feasibility of new treatment approaches. When such studies point to the feasibility of some new approach or technology, then efficacy studies involving proper experimental designs are indicated. Given that many of the studies in the present set of 37 appeared to be motivated primarily to explore the feasibility of new technological solutions to the participants' communication difficulties, the reliance on preexperimental evaluations would seem highly appropriate. Given that many of the 37 studies provided higher levels of [experimental] evidence suggests that these types of technology-based communication interventions were not only feasible, but also generally efficacious.

Not surprisingly, given the diversity of technologies used and the range of target skills, researchers employed a wide range of procedures in an attempt to achieve their intervention objectives. The intervention approaches or procedures that were used across these 37 studies could be classified into three broad categories. The first category involved the application of behavioral procedures. Such procedures are characterized by direct, systematic instruction involving application of techniques such as antecedent cueing, response prompting, prompt fading, and contingent reinforcement (Duker et al. 2004). This class of intervention procedures is exemplified, for example, in the study by Schepis et al. (1996) in which the three participants were taught to use SGDs to request preferred stimuli using antecedent instruction (i.e., *Show me what you would do if you wanted chocolate milk)* and contingent reinforcement. The studies by Lancioni et al. (2012a, b) also illustrate the application of behavioral procedures (i.e., response prompting and contingent reinforcement) for teaching adults with ALS to activate optic microswitches. The second category of intervention procedures could be viewed as involving the application of more symbolic learning procedures, such as verbal instruction and modeling. Illustrative of this type of intervention approach is the study by Pattee et al. (2006) in which verbal instruction and response modeling were used to teach the participant to use a text-to-speech device (LightWriter). The third category of procedure involved computer-based instruction, as illustrated in the study by Behrns et al. (2009). In this study, computer-based software programs were used to improve spelling and writing performance in three post-stroke participants.

While each of these three classes of intervention procedures (i.e., behavioral, symbolic, computer-based) were generally effective, the decision regarding which type of intervention approach to use would seem to depend to some extent on the abilities of the participants. Participants with good receptive language and imitation abilities, for example, may learn quite readily via more symbolic learning procedures (e.g., verbal instruction and modeling). Good literacy and computer keyboard skills might similarly represent important prerequisites for effective use of computer-based instructional approaches. Behavioral procedures, in contrast, are perhaps more likely to be indicated for individuals for whom symbolic and computer-based instruction is contraindicated, such as for individuals with significant cognitive, literacy, and receptive language deficits. The extent to which these implemented procedures were effective in producing positive intervention outcomes will now be considered for each of the three groups of studies.

Outcomes from studies involving persons with cerebral palsy. The overall trends from this first group of 13 studies could be seen as largely positive in that the participants' communication skills, and/or participation in communicative exchanges, seemed to have been aided by the assistive technologies employed in these studies. However, the range of outcomes varied across studies as might be expected given the varying subtypes and severity of cerebral palsy among the 18 total participants, their varying ages, the varying intervention goals and procedures, and the multitude of technologies that were applied and evaluated. In addition, the results of these studies must be interpreted with caution given that some studies relied on preexperimental designs (e.g., Mathisen et al. 2009) or did not directly evaluate an intervention per se (Clarke and Wilkinson 2007). Still, the 13 studies summarized in Table 4.1 provide illustrative examples of how assistive communication technologies have been used with individuals with cerebral palsy. Such examples may be extremely helpful to clinicians when they encounter individuals with similar characteristics and needs.

Outcomes of studies involving individuals with motor speech disorders. The ability to produce fluent, intelligible speech is often severely compromised by the motor control problems associated with apraxia, DAS, dysarthria, and ALS. The overall outcomes from this second group of 10 studies (Table 4.2) were generally positive in showing how assistive communication technology can be successfully applied to make use of the person's existing speech or to provide the person with an alternative (and more intelligible) mode of communication. The largely positive results from these 10 studies—including the generally favorable view towards their technological aides by the participants—suggests that such technology has an important role to play in the rehabilitation of persons with apraxia/DAS, dysarthria, ALS, and perhaps other communication disorders related to impairment of motor control.

Outcomes of studies involving individuals with aphasia. Overall, with respect to the 14 studies summarized in Table 4.3, the outcomes of these studies were also generally positive in that most participants showed gains in the targeted communication skills. However, these gains could not always be attributed to the intervention procedures and use of the assistive communication technology, given that many of the studies relied on preexperimental designs (e.g., one-group, pre-post testing) to evaluate the effects of the intervention. In addition, mixed results were often obtained with respect to either the number of participants within a study who showed gains and/or the extent of gains across different dependent measures. On the positive side, several studies included opportunities for participants to practice using the technology for several weeks and months and also assessed participant satisfaction with the assistive communication technology. The opportunity for such extended "test drives" so to speak would seem to be a useful component with respect to the evaluation of assistive communication technology.

Overall summary of outcomes. The collective results of these 37 studies cannot be directly compared due to the fact that the studies differed greatly in terms of participants' diagnoses, ages, type of assistive technology, communication areas and skills targeted, experimental rigor, and intervention approaches. Still, the general trends from the 37 studies summarized in this chapter reported generally positive results. While some participants failed to show much progress on some of the targeted dependent measures, most of the participants in these studies showed improvement on at least some aspects of communication that were related to the use of the assistive communication technology. These generally positive findings establish an emerging evidence base and a suite of empirically validated procedures for enabling effective use of this range of assistive communication technologies in the treatment of a number of the communication difficulties experienced by people with cerebral palsy, apraxia, dysarthria, ALS, and aphasia. This conclusion is consistent with the findings of previous systematic reviews that have focused on the use of SGDs among individuals with autism (van der Meer and Rispoli 2010), intellectual disabilities (Rispoli et al. 2010; Sutherland et al. 2010), and severe/profound and multiple disabilities (Lancioni et al. 2013). The present overview of 37 studies extends these previous reviews by focusing on a wider range of assistive communication technologies and the treatment of a wider range of communication disorders.

Implications for Practice

The generally positive results from these 37 studies have several implications for practice. Practice in this context refers not only to prescribing assistive technology, but also to intervention design, implementation, and evaluation. The evidence from this set of 37 studies suggests that in most cases, participants will require some form of intervention to ensure that the person learns to use the technology effectively. The results of 37 studies also have implications for evaluating the outcomes of the technology and intervention.

With respect to the prescription or selection of assistive technology, one of the trends in this literature is a shift to more participant-driven practices. That is, moving away from a model in which assistive technology is prescribed by a clinician—based on an assessment of participant characteristics and needs—to a model in which the participant is more actively involved in selecting assistive technology options. For example, Lancioni et al. (2012b) adoption of optic microswitch solutions was based in part on the results of their prior consultation with the two participants. The study by Pattee et al. (2006) illustrated the critical importance of enabling greater self-determination among persons who might be considered good candidates for some form of assistive communication technology. In that study, the participant showed a preference for using a low-tech sign language system over the high-tech communication device (i.e., LightWriter). The obvious implication here is the need for efficient and valid methods for enabling participants to provide input and express their preferences in relation to assistive communication technologies. While adequate exposure to the technology is necessary to ensure participants are able to make informed choices, expressing valid preferences would also seem to require comparable exposure to a range of options and then choosing the preferred option. Along these lines, van der Meer et al. (2011) described procedures that have been successfully used to assess participants' preferences for different AAC options. These procedures, which consist of teaching individuals to use one or more options and then creating opportunities to choose among the options, appear to yield a valid indication of preference. Similar procedures would seem applicable for assessing preference for using the different types of assistive technologies described in the present set of 37 studies.

With respect to the intervention design, implementation, and evaluation, different types and intensities of intervention were employed. In some cases, the amount and type of intervention that was required was relatively minimal (e.g., showing and telling the person what to do). This level of intervention would obviously be more efficient and cost-effective than some more intensive behavioral intervention that had to be implemented on a daily basis over several weeks. While it might thus be tempting to provide only minimal intervention, this is unlikely to be sufficient for more severely disabled participants or with more complicated technology or when teaching more advanced communication skills. However, it is difficult to predict the amount and type of intervention required by any given individual or for any given type of technology or when teaching a particular communication skill. One possible solution might thus be to follow a generic intervention approach that lends itself to individualization with respect to the intensity and type of intervention. Our review of these 37 studies suggests three generic and sequential intervention phases that were common to most of the studies. First, participants generally received an initial period of training to ensure they learned to use the technology for the intended purpose(s). It is at this initial stage where the intensity and type of intervention could be individualized in response to whether or not the participant makes sufficient progress. Second, participants would next receive a prolonged trial period during which they could practice using the technology in their everyday environments. This phase is intended to build fluency. Third, satisfaction with the technology should be assessed and any problems/concerns addressed in a subsequent modified intervention. For example, following an extended trial, participants might report the frequent need to reply to spoken questions from naturally speaking peers with a simple *yes* or *no* response. In such cases, the technology might need to be reconfigured to ensure frequently used communication responses can be produced quickly and with little fatigue. The implication here is the need for clinicians to view the provision of assistive communication technology as part of a sequence that includes individualized instruction, extended practice, assessment of satisfaction, and troubleshooting.

Along these lines, there is likely to be a need to troubleshoot or reconfigure assistive technology solutions in light of participants' changing circumstances. Participants with ALS, for example, may lose motor skills over time and thus require adaptations to their assistive technology. In other cases, participants may outgrow their assistive technology due to effective intervention and thus require equipment/skill upgrades. Given the range of possible changes, both positive and negative, there is a need to regularly (re)assess the person's circumstances. One aim of such assessments should be to match the assistive technology and the associated intervention to the unique characteristics of the individual. As noted by Hill and Corsi (2012), the outcome of such assessments may suggest a change in the aim of intervention. This change could range from a focus on regaining lost skills to maintaining one or more communication skills/functions to teaching new communication skills (e.g., texting, Skyping).

Another implication arising from our summary and analysis of these 37 studies is that by establishing the potential viability of a range of assistive communication technology, there is evidence to support clinical application of such devices in treatment programs for individuals with these types of communication disorders. There is thus likely to be a corresponding need for developing effective training procedures to ensure clinicians and other relevant stakeholders gain the necessary competencies to program and maintain the participant's assistive communication technology. Stakeholders also will need to learn how to interact effectively via the assistive technology, such as how to create opportunities for use of the technology and how to respond most effectively to the person's technology-assisted communications.

Future Research Directions

Several directions for future research arise in light of this review of studies. First, the literature to date is characterized by preexperimental feasibility studies and experimental [albeit small-n] efficacy studies. Given the largely promising results from these two classes of studies, there would seem to be value in systematic replications to extend the generality of the findings (Sidman 1960). Studies aimed at identifying what types of assistive technologies/interventions are likely to be most helpful in the long term for different types of communication problems should also be pursued. The current trial and error approach with limited follow-up is inefficient. Studies that could contribute to the development of empirically based guidelines for the use of assistive communication technologies would facilitate evidence-based practice in communication disorders. New assistive technologies will continue to emerge and should also be the focus of future feasibility and efficacy studies.

Second, while this set of 37 studies covered a range of communication disorders, communication skills, intervention procedures, and assistive technologies, the literature has gaps in relation to the settings in which these interventions were applied and the technologies used. Specifically, there are very few studies exploring community use of assistive communication technologies. The value of assistive communication technologies would seem to depend to some extent on how well they work across a range of community settings and communication partners. Community-based studies could thus be seen as a critical area for future research. A possibly important aspect of such community evaluations might be to consider the perceptions of people in the community regarding their interactions with people with communication disorders who either do or do not use assistive communication technologies. That is, there is a need for assessing the ecological and social validity of assistive communication technologies.

Third, while the present set of 37 studies targeted a range of useful communication skills, the present literature base could be improved by studies that aimed to examine the wider impact of assistive communication technologies on other domains. Communication is often considered a pivotal response (Koegel et al. 1999). As such, improvement in the communication domain might be expected to impact on other areas of functioning, such as social engagement or academic achievement. It is unclear if any such wider impact will occur when the target communication functions/skills are accomplished via assistive communication technology.

As suggested by our summary and analysis of Raghavendra and Oaten's (2007) study, a fourth area for future research would be to study whether the type of feedback provided by the assistive technology is an important variable in relation to the ease and speed with which individuals learn to use assistive technology for various communication-related purposes. So far, studies have focused on comparing print versus speech feedback for spelling (Raghavendra and Oaten 2007; Schlosser et al. 1998). An obvious direction for future research would be to extend this type of study to compare other types of feedback—both from the assistive technology itself and from the communicative partner—and to other aspects of communication, such as answering questions, commenting on the environment, making requests, and conversational turn-taking.

Conclusion

The studies reviewed in this chapter illustrated the use of assistive technologies for enhancing the communication skills of people with cerebral palsy, apraxia, dysarthria, ALS, and aphasia. The range of assistive technologies evaluated included SGDs, speech recognition software, microswitches, and computer software programs. These options were used to improve a range of communication skills, including requesting, asking/answering questions, naming pictures, communication, spelling/writing, sending/reading text messages, and making cell phone/Skype calls. To achieve these goals, three main classes of intervention procedures were implemented (i.e., verbal instruction plus modeling, behavioral intervention, and computer-based instruction). While the methodological quality of the studies varied, the overall outcomes were positive. We conclude there is sufficient evidence to support the use of assistive technology in the treatment of communication disorders associated with cerebral palsy, apraxia, dysarthria, ALS, and aphasia. This conclusion has implications for treatment, but additional research is needed to advance evidence-based practice related to the use of assistive technology in the treatment of communication disorders.

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Chapter 5
Assistive Technology for Students with Visual Impairments and Blindness

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Introduction

The use of assistive technology (AT) with students with visual impairments (VI) and blindness has the potential to improve many student outcomes related to academics and learning (e.g., Bouck et al. 2011; Bowers et al. 2001; Ferrell 2006; Lovie-Kitchin et al. 2001; Spindler 2006; Theoret et al. 2004). Impairments in vision render students with VI and blindness frequently unable to make use of many common objects in schools, such as written instructional materials and computer screens. These impairments also restrict incidental learning opportunities that typically developing students access visually, such as observing others' skill demonstrations and witnessing examples of functional relationships (Hyvarinen 2000). Assistive technologies provide students with VI and blindness access to many school-related activities by enhancing existing sight abilities or drawing on other senses (e.g., hearing) and abilities (e.g., oral language).

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This chapter strives to provide examples, explanations, research findings, and implications for use of AT with students with VI and blindness. First, we discuss various definitions of VI and blindness, prevalence of the impairments, common challenges associated with VI and blindness, and the process of fitting AT to students. We then focus on explanations and research findings on AT-relevant assessments of VI and blindness, and AT for pre-academic learning, reading, writing, mathematics, and science students. For each domain of learning, discussions of AT items are grouped according to whether the AT enhances the sight capabilities of users or engages senses and abilities other than sight. Last, we conclude by addressing a number of clinical and academic implications of use of AT with students with VI and blindness, including implications related to assessment, AT selection, teaching and encouraging use of AT, technology abandonment, and future research.

Definitions of Visual Impairment and Blindness

Several different perspectives on VI and blindness have given rise to multiple definitions and conceptualizations of the impairments. These include (a) a focus on the anatomy and etiology of impairments; (b) an emphasis of a person's visual acuity and visual field; and (c) attention to the functional capabilities and limitations of a person's vision. Each approach to defining an impairment is relevant to designing and evaluating AT supports for students with VI and blindness; however, definitions related to visual acuity, visual field, and functional limitations are often most useful to the work of educators (Faye 1996; Individuals with Disabilities Education Improvement Act of 2004 [IDEA] 2004b).

Anatomic and etiological definitions. The medical community has identified a wide variety of disease conditions and anatomical anomalies that lead to VI and blindness (American Foundation for the Blind [AFB] 2013a). These conditions and anomalies can be congenital, meaning they are present at or near the time of a person's birth, or adventitious, meaning they were acquired after birth, during childhood, or some point later. Some of the most common disease conditions and anatomical anomalies include:

1. cortical visual impairment—damage to the visual cortex, temporal lobes, and/or parietal lobes of the brain (e.g., by oxygen deprivation or infections of the central nervous system) which disrupts the receiving and decoding of information sent by the eyes;
2. retinopathy of prematurity—damage to the retina by blood vessel overgrowth and the resulting scar tissue which is associated with premature birth;
3. optic nerve hypoplasia—underdevelopment of the optic nerve, that transmits information to the brain, and possibly midline structures in the brain;

4. strabismus—misalignment of the eyes resulting from abnormal development of eye muscles, nerves which supply the eye muscles, or brain regions controlling eye movement;
5. amblyopia—regression in the function of an eye due to chronic obstruction of vision in the eye, strabismus, or refractive differences between the two eyes;
6. nystagmus—a rapid jiggling back and forth of the eyes that interrupts fixation on objects and which results from underdevelopment of the optic nerve or fovea, or a variety of rod or cone abnormalities (Hatton 2001).

In addition to these conditions and anomalies, VI and blindness can also result as collateral outcomes of traumatic brain injury, severe eye infections, tumors, and diabetes (Geddie et al. 2013).

As mentioned above, the anatomic and etiological factors involved in a person's visual impairment often have little relevance to the design and evaluation of AT supports for students with VI and blindness. The cause of visual loss frequently does not provide information on the residual vision possessed by a person or her ability to make use of vision in functional tasks (Hyvarinen 2000). Further, research has shown that the cause of visual loss is not associated with the degree of delay in developmental milestone acquisitions (Frailberg 1977). However, understanding the anatomic and etiological factors involved in a person's visual impairment can be critically important to the success of treatment initiated by ophthalmologists, optometrists, and neurologists (Matta et al. 2010).

Visual acuity- and visual field-based definitions. The terms *low vision* and *legally blind* are based on measurements of a person's visual acuity and visual field. Visual acuity is an index of the sharpness or clearness of vision (Cline et al. 1997), and is measured by requiring a person to identify symbols on a chart at a distance. The likely familiar 20/20 rating represents nominal vision. A rating of 20/40 implies a person, when at a distance of 20 feet, can identify symbols that a person with nominal vision can identify at a distance of 40 feet. Visual field is the scope of vision (Geddie et al. 2013). Testing of visual field includes measuring the range of a person's central and peripheral visual fields, and results in identification of scotomas (i.e., areas of partially or entirely diminished visual acuity). Normal visual fields are defined as extending roughly 60° toward the nose, 100° away from the nose, 60° upward, and 70° downward (Spector 1990). Individuals are identified as having low vision when they have visual acuity of 20/70 to 20/200 in the better eye after correction (i.e., with eyeglasses or contacts) or a visual field limited to 20–40° after correction (Brilliant 1999). Legal blindness is typically defined as visual acuity of less than 20/200 in the better eye after correction or a visual field limited to less than 20° (Koestler 2004). It's important to note that legal blindness differs from common conceptions of blindness (Huebner 2000). Whereas individuals with legal blindness may have some functional residual vision, individuals identified as blind have either no vision or only the ability to perceive the presence of light.

While use of the labels *low vision*, *legally blind*, and *blind* don't necessarily aid the design and evaluation of AT supports for students with VI and blindness, knowledge of a person's visual acuity, visual field, and extent of light perception can. Generally, when considering a student's ability to perform specific tasks, information regarding visual acuity, visual field, and light perception guides selection of supports for use of residual vision and/or suggests utilization of supports that engage a student's other senses and abilities. The use of information on visual acuity, visual field, and light perception is discussed further throughout the chapter.

Functional categories of visual impairments. Vision impairment can also be conceptualized in terms of functional effects of the involved eye disorder(s) and severity of the impairment. The most useful information for the design and evaluation of AT supports for students with VI and blindness derives from descriptions of the functional effects of eye disorders (Faye 1984, 1996; Hyvarinen 2000; Topor and Erin 2000).

Functional effects of eye disorders. The effects of eye disorders fall into three categories: media pathologies, central visual field defects, and constricted fields or peripheral scotomas (Faye 1984, 1996). Media pathologies produce blurred or hazy vision, reduced contrast sensitivity, and, possibly, increased experience of glare. These effects result from diseases and anatomical anomalies (e.g., cataracts) that affect the optical media (i.e., cornea, pupil, lens, and vitreous). Supports for students with media pathologies should emphasize refraction (e.g., via eyeglasses), control of illumination, and enhancement of contrast. Central visual field defects reduce perception of details and color in the direct line of sight, both at close and far distances. Such defects result from diseases and anatomical anomalies that affect the cone-bearing fovea and macular area of the eyes. Supports for students with central field defects should draw on and maximize peripheral vision through magnification and enhancement of contrast. Constricted fields, or peripheral scotomas, reduce perception of details and color outside the direct line of sight. Notably, constricted fields interfere with orientation in space and cause difficulty in locating objects. When the degree of field constriction is great (i.e., vision is constricted to the cones in the center of the eye), night blindness can result. Such functional effects result from a variety of conditions, such as glaucoma, head trauma, stroke, and retinitis pegmentosa. Supports for students with constricted fields should emphasize magnification and address orientation and mobility needs.

Severity of impairment. Visual impairments are often classified as mild, moderate, severe, or profound; however, no criteria have been put forward for objectively delineating these categories (Bergwerk 2011; Friend 2011). Students with low vision are often considered to have mild to moderate VI. Impairments which qualify as legal blindness can range from moderate to profound, while blindness unarguably constitutes a profound VI. When planning supports for students with VI and blindness, the relative emphasis of AT that enhances vision and AT that draws on other senses and abilities should be in accord with the severity of the student's impairments.

Prevalence of Visual Impairments and Blindness

The prevalence of VI and blindness is estimated at 1 to 5 % of the population (American Academy of Ophthalmology 2002; Mason et al. 2000; Multi-ethnic Pediatric Eye Disease Study Group 2008). The prevalence varies across countries and is generally greater in developing countries, where nutritional disorders (e.g., vitamin A deficiencies) and infections (e.g., trachoma, measles) are common (Geddie et al. 2013). In the United States, determining the actual prevalence is problematic because no comprehensive registry exists and the different databases define VI differently and focus on limited age ranges (Kirchner and Diamant 1999; Mason et al. 2000). For example, the United States Department of Education maintains counts of the number of students who receive special education services by disability category. Students who have multiple disabilities (e.g., blindness and intellectual disability) are counted only once (e.g., as having a VI, an intellectual disability, or multiple disabilities). Students with VI are presumably often counted in categories other than VI, at unknown relative rates. This is particularly problematic for estimating prevalence because between one-third of children with some residual vision and two-thirds of children with blindness have one or more additional disabilities (Kirchner and Diamant 1999; Mervis et al. 2000).

Challenges Associated with Visual Impairments and Blindness

Visual impairments and blindness pose a number of developmental challenges to affected children. The conditions can detrimentally influence physical, cognitive, linguistic, social, and academic development, as well as contribute to the development of problem behaviors (Baillargeon 1993; Bergwerk 2011; Brodsky 2010; Fazzi et al. 1999; Houwen et al. 2010; Hyvarinen 2000; Perez-Pereira and Conti-Ramsden 1999). A variety of factors appear to moderate the effects of VI and blindness on an individual's developmental outcomes. These include the amount of residual vision, the presence and severity of other disability conditions, the overall health of the individual, the amount of support provided to and accepted by the individual, the quality of support provided by teachers, therapists, and parents, and the educational attainment and occupational choices of the individual (Davidson and Quinn 2011; Frailberg 1977; Hatton et al. 1997). Theoretically, by extension, provision of AT supports seems likely to improve students' developmental outcomes.

Challenges to physical development. With regard to physical development, impairments in vision can hinder learning of oculomotor and other motor skills (Bergwerk 2011; Brodsky 2010; Frailberg 1977; Hyvarinen 2000). For example, increases in falling and timidity, especially in new environments, and delays in development of balance, posture, and self-initiated mobility have been observed in infants and toddlers with VI and blindness. Also, many motor skills are typically learned incidentally, via modeling (Brodsky 2010; Hyvarinen 2000). Children with VI and blindness often are unable to utilize such skill demonstrations. Support for development of motor skills in children with VI and blindness is especially important, as decreased motor development in the population is associated with lower levels of physical fitness and higher rates of obesity (Houwen et al. 2010).

Challenges to cognitive development. Children with VI and blindness often experience delayed development of cognition related to spatial concepts (Baillargeon 1993; Hyvarinen 2000). During infancy, children typically develop depth perception and understandings of ego-centric space and object permanence while manipulating objects with their hands and watching the effects of their movements. While many opportunities exist for children with VI and blindness to learn spatial concepts, implementation of supports for early learning is crucial for preventing delays in their cognitive development.

Challenges to linguistic development. Impairments of vision can disrupt and delay the development of preverbal, verbal, and nonverbal language (Brodsky 2010; Perez-Pereira and Conti-Ramsden 1999). The learning of preverbal and nonverbal communication typically involves observation and imitation of others' movements (e.g., of the lips or head). Linguistic development in children with VI and blindness is often instead driven by the sense of hearing. Research has shown that children with VI and blindness use less body and facial language, have difficulty with pragmatics and pronouns (e.g., incorrectly say "you" for "I"), and have less developed conversation skills (Perez-Pereira and Conti-Ramsden 1999). However, children with VI and blindness who have average intelligence or greater often attain typical levels of verbal language proficiency by mid-childhood.

Challenges to social development. With regard to social development, VI and blindness can negatively impact bonding, attachment, and social interaction (Brodsky 2010; Hyvarinen 2000). Much of the bonding and attachment of infants with caregivers is facilitated by eye contact. Similarly, eye contact and vision are central to social interaction and the development of social skills. For example, in a case study of an infant with VI who was delayed in development of social interaction, the provision of eyeglasses immediately resulted in first an expression of surprise, and then a social smile coupled with eye contact (Schwartz et al. 1997). Based on the infant's previous failures to engage socially, the medical professionals working with her had formed the hypothesis that she had an autism spectrum disorder. The results of provision of eyeglasses, however, revealed that the infant's inability to perceive faces had prevented her from developing age-appropriate social behaviors.

Risk of problem behavior. Students with VI and blindness, like many other individuals with disabilities, are at risk for developing problem behaviors (e.g., Conley and Worley 1980; Lalli et al. 1996). For example, children who have impaired night vision may cope with a fear of the dark or inability to navigate independently with behaviors, such as tantruming or screaming, that function to enable their escape from the overwhelming challenges or otherwise aversive stimuli via recruitment of caregivers' assistance (Bergwerk 2011). Individuals with

VI and blindness may also develop atypical self-stimulatory behaviors (e.g., pressing on eyes, waving fingers in front of eyes; Fazzi et al. 1999) or problem behaviors that function to provide access to objects or the attention of others they have difficulty locating or reaching. Such problem behaviors can be successfully extinguished and replaced with functionally-equivalent positive behaviors through behavioral intervention (Alberto and Troutman 2012).

Challenges to academic development. Vision impairments and blindness have the potential to disrupt students' academic learning in traditional, mainstream educational settings. In the past two centuries, many instructional strategies and materials, as well as assistive technologies, have been developed for enabling the learning of students with VI and blindness (Friend 2011). While some students still encounter learning and performance barriers (e.g., in advanced chemistry courses; Supalo et al. 2006), the numbers of these barriers are progressively decreasing with time.

Early detection and intervention with children with VI and blindness is crucial to maximizing their potential for vision and improving their developmental trajectory (Mills 1999; Oldham and Steiner 2010). The current consensus in the medical community is that children pass through a critical period of visual development, lasting from birth to age 6, after which learning of vision skills occurs much less efficiently and the physiological processes of development slow or halt (Groenendaal and Van Hof-Van Duin 1992; Tavernier 1993). Research on early intervention programs corroborates this view; findings suggest treatment success is inversely related to children's age at the time of enrollment (Mills 1999).

Overview of the Process of Fitting Assistive Technologies to Students with Visual Impairments and Blindness

The goals of implementing AT with students with VI and blindness are to increase or improve their functional capabilities, support their education and development, and facilitate their independence (Desch 2013; IDEA 2004c; Sadao and Robinson 2010). Professionals in the field of AT assert these goals can best be achieved by engagement in a standard sequence of procedures for fitting AT to students (e.g., Bryant and Bryant 2003; Cook and Hussey 2002). The process should begin with assessments of the student's skills and abilities, functional limitations, and learning needs, as well as task analyses of activities for which they will receive support. The resulting information should then be used to select AT devices that draw on the student's existing skills and abilities, improve their functional capabilities, and enable their full participation in target activities. When implementing the selected AT, professionals should consult the research literature to identify AT that has the greatest likelihood of effectiveness, take care to obtain the buy-in of the students regarding the AT, confirm use of the AT is convenient and effective, and provide training to the student and others who may support his use of the AT. Finally, periodic and/or on-going evaluations should be carried out regarding the success of implementation of the AT, the device's state of repair, and the goodness of fit among the student's learning needs, skills, functional limitations, and activities for which she needs support. Issues related to assessment, decision making regarding AT, teaching and encouraging use of AT, and evaluation of AT supports are discussed further throughout the chapter.

Research Review

In this section, we provide explanations and research findings on AT-relevant assessments of VI and blindness and AT for pre-academic learning and reading, writing, mathematics, and science students. For each domain of learning, discussions of AT items are grouped according to whether the AT enhances the sight capabilities of users or engages senses and abilities other than sight.

For some AT items discussed below, little or no research has been conducted to investigate or comparatively evaluate devices' effectiveness in improving individual's functional capabilities. Instead, the intuitive appeal of the AT and anecdotes of improved functioning with use of the devices have led to their widespread acceptance and promotion (Hyvarinen 2000). For items for which no research has been conducted, discussion is limited to description of their features and explanation of their potential uses.

Assessment

The extent and quality of assessment are critical determinants of long-term AT implementation outcomes of students with VI and blindness (Day et al. 2001). Research has shown that when one's needs were not fully identified and addressed during the AT assessment and selection process, dissatisfaction with and abandonment of AT are likely (Cook 1982; Zola 1982). To comprehensively document the support needs of students with VI and blindness, and improve the likelihood of student satisfaction and implementation success, professionals from several disciplines conduct assessments of students' visual acuity, visual field, functional use of vision, and preferences for learning media (Faye 1996, 1984; Hyvarinen 2000; Topor and Erin 2000). Results of the assessments are used in planning AT supports, as well as related services, school-based accommodations and curriculum modifications (Friend 2011).

Visual acuity and visual field assessments. As mentioned above, assessment of visual acuity involves requests to identify symbols on a chart at a distance and determines the sharpness or clearness of an individual's vision (Cline et al. 1997). Assessment of visual field involves requests to identify the location of objects in central and peripheral visual fields, and results in identification of scotomas (i.e., areas of partially or entirely diminished visual acuity; Geddie et al. 2013). These types of assessment are performed by medical professionals such as primary care physicians, pediatric neurologists, ophthalmologists, and optometrists. These professionals, as well as certified low vision specialists and teachers of students with VI, use the resulting information to select optical aids to support individuals' use of their residual vision (e.g., eyeglasses, telescopes, closed-circuit television [CCTV]; Faye 1996, 1984; Hyvarinen 2000), plan environmental arrangements (e.g., classroom seating; IRIS Center for Teaching Enhancements 2012), and identify skills for instruction (e.g., how to hold materials at appropriate distances or locations in the visual field; Topor and Erin 2000). To ensure validity of results, professionals who assess students' visual acuity and visual field should use age- and ability-appropriate assessment procedures (Bergwerk 2011; Chou et al. 2011; Committee on Practice and Ambulatory Medicine Section on Ophthalmology, American Association of Certified Orthoptists, American Association for Pediatric Ophthalmology and Strabismus, and American Academy of Ophthalmology 2003; Geddie et al. 2013; Hyvarinen 2000; Topor and Erin 2000; US Preventative Task Force 2011; Utely et al. 1983). For example, consideration should be given to (a) individuals' capacity for cooperation, (b) recognition of symbols, (c) communication of visual experiences, as well as (d) the maturity of the visual system, (e) development of visual behavior (e.g., preferential looking, eye contact), and (f) possible effects of comorbid disabilities. The literature suggests a variety of strategies for addressing challenges to assessment, including (a) use of nonconventional symbols recognized by and meaningful to the student, (b) establishment of fluency with or creation of names for symbols prior to assessment, (c) use of single symbol cards, (d) prompting of alternative responses such as yes/no, gestures, and eye-blinks, (e) engagement of students in interactive tasks (e.g., activating lights in the visual field), (f) assessment of vision in nonconventional, familiar, and/or preferred environments (e.g., a plastic ball pool), (g) segmentation of assessment into a series of short sessions, and (h) use of vision screening technologies (e.g., electroretinogram, electrooculogram, magnetic resonance imaging).

Functional vision assessment. Functional vision assessment evaluates how a student uses vision to complete functional tasks and determines the extent to which the visual disability affects learning (Corn and Webne 2001; Erin 1996; Hyvarinen 2000; Topor and Erin 2000). These assessments are typically performed by teachers of students with VI, who use the results to formulate plans for AT, specialized instruction, and environmental adaptations that increase the efficiency of a student's visual functioning. On occasion, functional vision assessments also uncover needs for additional evaluation(s) related to vision or other functional domains. Of primary interest in the assessment are the questions: (a) what is the range of a student's visual functioning across various lighting, contrast, and color conditions, levels of motivation, and durations of activity?; (b) how does the student function in developmentally appropriate functional tasks and typical, age-specific classroom environments?; and (c) what visual information will need to be compensated for by other modalities? In answering these questions the assessor identifies specific tasks, circumstances, and sensory input for which the student needs support in the form of AT, specialized instruction, and/or environmental adaptations.

Since the environments and abilities of students with VI and blindness vary greatly, no standardized functional vision assessments exist (Shaw et al. 2009). Instead, professionals may use a variety of established instruments or self-developed techniques which involve direct and/or indirect observation, and generate quantitative and/or narrative format results (Bishop 2004; Erin and Paul 1996). While such customization of the assessment process fits the diversity of student profiles and is generally regarded as good practice, no research has investigated the reliability of assessment findings across examiners or varying combinations of assessment methods. As in assessments of visual acuity and visual field, use of age- and ability-appropriate assessment procedures can improve the validity of results (Hyvarinen 2000; Topor and Erin 2000; Utely et al. 1983).

Several authors have published instruments for use in functional vision assessments. These include the Individualized Systematic Assessment of Visual Efficiency (ISAVE; Langley 1998), Functional Vision and Learning Media Assessment (FVLMA; Burnett and Sanford 2008), and Cortical Visual Impairment Range (CVI-Range; Roman-Lantzy 2007). Investigations of the methodological properties of these instruments are limited to assessments of the reliability of the CVI-Range. Newcombe (2010) found the assessment had high internal consistency, test–retest reliability, and inter-rater reliability. When conducting functional vision assessments, professionals may additionally find useful general functioning assessments, such as the International Classification of Functioning, Disability and Health (World Health Organization 2001), Functional Independence Measure for Children (Wong et al. 2005), and the Pediatric Disability Inventory (Ostensjo et al. 2006).

Learning media assessment. Learning media assessment documents a student's preferred sensory channel(s) (i.e., vision, touch, or hearing) and facilitates identification of optimal instructional materials (e.g., pictures, rulers, worksheets), instructional methods (e.g., demonstration, modeling, prompting), and literacy media (e.g., print, Braille) for the student (Koenig and Holbrook 1995). Documentation of a student's sensory channel preferences involves direct observation of the student's interactions with learning media in a variety of settings, recording of observable behaviors, and notation of what sensory channels the student appeared to use in performing the behavior. When data collection is complete, observers make overall tallies of use of each sensory channel and attempt to identify patterns between sensory channel use and features of the environments or activities. Subsequently, the observers or other educational professionals who work with the student peruse extensive lists of instructional materials, instructional methods, and literacy media, organized by the sensory channels each engages, and select media that match the student's identified sensory preferences. Assessment is often re-conducted periodically to determine the adequacy of the learning media implemented with the student.

Authors have published two learning media assessments: the Learning Media Assessment of Students with Visual Impairments (Koenig and Holbrook 1995) and the above-mentioned Functional Vision and Learning Media Assessment (FVLMA; Burnett and Sanford 2008). Assessment materials for each include extensive lists of learning media organized by the sensory channels engaged. The methodological properties of the assessments have not been investigated; however, each has been field tested and experts confirmed they have face validity (American Print House for the Blind 2013; Koenig 1999).

Assistive Technologies for Pre-Academic Learning

As mentioned above, supporting the learning of young children with VI and blindness can improve their academic and functional outcomes at later stages of their education (Groenendaal and Van Hof-Van Duin 1992; Mills 1999; Oldham and Steiner 2010; Tavernier 1993). Theoretically, the development of visual behaviors, haptic awareness, and fine motor skills, and the use of residual vision in play and social interaction enable the learning of more sophisticated and complex functional behaviors and skills in subsequent years. Below, we describe technologies that may support early learning in children with VI and blindness, and the limited research that supports their use.

Technologies that Enhance Sight Capabilities

Toys and adapted play areas. The development of vision, visual behavior, and proprioception in infants is facilitated by manipulation and attending to objects and their hands (Baillargeon 1993; Hyvarinen 2000). Visual impairments may interrupt these developments. To draw infants' attention to objects and their hands, and encourage use of their residual vision, authors have suggested provision of toys that give off light or glow, are marked with bright colors, and/or produce sound (Holbrook 2006; Hyvarinen 2000).

Facial treatments. The development of language in young infants appears to be aided by watching and copying others' lip and tongue movements (Baillargeon 1993; Hyvarinen 2000). Authors have suggested the use of make-up and lighting may improve the ability of infants with VI to perceive others' lip and tongue movements (Holbrook 2006; Hyvarinen 2000). For example, lips can be outlined with a brown contour pen and/or highlighted with lipstick, and light sources can be directed at the face.

Electronic vision enhancement systems. At young ages, children learn to understand pictures as representations of objects (Brandsborg 1996; Hyvarinen 2000). In children with VI, this learning may be disrupted by the use of eyeglasses or other lens-based optical aids, which can result in the division of an image into segments. Perception of only a segment of an image at a given time poses an obstacle to learning in that young children typically do not have the cognitive capability to view segments of an image, recognize their relationships to the whole image, and infer their representation of the whole image.

Electronic vision enhancement systems (EVES), also known as closed-circuit televisions (CCTV) can facilitate the viewing of whole images and have been suggested as supports for children's learning related to picture representations (Hyvarinen 2000). EVES involve video cameras and real-time display of images on screens (Wolffsohn and Peterson 2003). The devices range in size from large desktop units to hand-held devices, and transmit images to TVs, computer monitors, in-built screens, or head-mounted displays. EVES enable variable magnification (e.g., 2X to 60X) and image manipulation (e.g., reversing image contrast, altering colors).

Technologies that Engage Senses and Abilities Other than Sight

Development of haptic awareness and later learning of Braille may be supported by a variety of play items designed to engage children's sense of touch and exercise their haptic awareness (Holbrook 2006; Hyvarinen 2000). For example, research has shown play with textured toys can promote use of the visual cortex for tactile processing in children with VI (Theoret et al. 2004). Also, engagement with Braille readiness books, that present textures and raised shapes and symbols, has been found to improve children's fine motor skills and tactile sensitivity development (Roth and Fee 2011).

Assistive Technologies for Reading

The act of reading is central to many learning tasks in contemporary schools (Atlick 1998; De Castell et al. 1986; Friend 2011). In addition to granting access to educational materials, literacy is a requisite skill for a wide range of work-related, leisure, and life maintenance activities in modernized societies (e.g., Graff 1978; Norris and Phillips 2003). Fittingly, provision and instruction in use of alternative reading materials typically comprise the primary efforts of teachers of students with VI and blindness (Friend 2011; Galvin and Scherer 2004). Below, we describe various technologies that support reading, learning and performance in students with VI and blindness, and when possible, we summarize research on their use.

Technologies that Enhance Sight Capabilities

Large print text. Individuals with low vision may have difficulty viewing small print and making the optical movements required for reading text (American Foundation for the Blind [AFB] 2013f). One possible solution for increasing the readability of text is to use large print (AFB 2013b, f). Large print documents typically make use of font sizes 18 or greater (AFB 2013b; Kitchel 2013). While font size is an important component of large print documents, other factors such as the size of margins and spaces among lines of text, font type, color contrast, number of characters per line, and the distance between the reader and text materials can influence readability and should be manipulated according to the reader's abilities (AFB, 2013f; Kitchel 2013; Lueck et al. 2003). A variety of large print documents such as books, calendars, address books, and labels are commercially available through websites, such as Abledata.com, and print houses, such as American Printing House for the Blind and American Foundation for the Blind. Word processors can also be used to create large print documents for on-screen viewing or for printing (Evans and Blenkhorn 2004).

Research on the efficacy of large print documents has generally demonstrated positive correlations between improvements in reading rates (e.g., words read per minute) and increases in print size for individuals with low vision (Bangor 1998; Lueck et al. 2003; Lovie-Kitchin et al. 2001). Further, visual acuity and age appear to moderate the effects of large print on reading rates (Lovie-Kitchin et al. 2001). For example, Lueck et al. (2003) found the reading rates of fourth graders with low vision tended to decrease with decreases in text size and increase with increases in font size until the diagonal dimensions of letters were about two to four times greater than the individuals' minimum threshold for identification. The researchers hypothesized that the increases in eye and head movements required to read larger fonts prevented further increases in rate. Additionally, participants with relatively better visual acuity had greater increases in rate as text size increased than those with poorer acuity. In another study with students with low vision, ages 7 to 18, the majority of children achieved near normal reading rates with large print sizes (Lovie-Kitchin et al 2001). The study results indicated age and visual acuity were associated with the magnitude of individuals gains in reading rates. To further illustrate, in a study conducted with legally blind students font sizes of text displayed on a computer screen of 12 to 14 were too small to read. However, participants successfully read font sizes of 18, 24, and 30 (Bangor 1998).

While research supports relationships between print size and reading abilities for individuals with VI, studies that compared vision aid use with standard print to large print use alone obtained mixed findings. In a study conducted with legally blind and partially sighted students, test scores on a large print form of a reading test were not substantially higher than scores on a test in font size 10 when optical aids (e.g., magnifiers, glasses) and non-optical aids (e.g., reading lamps and reading stands) were used (Sykes 1971). Measures of reading comprehension and reading rate were not significantly different across conditions, and use of large print was not associated with decreases in reading distances. The partially sighted participants did, however, report less visual fatigue after reading the large print. In contrast, Farmer and Morse (2007) found magnifiers conferred greater benefit than large print documents. Oral reading tests were conducted at the beginning and end of a school year with students with low vision. In reading instruction during the school year, the students received either large print materials or typical sized print materials and magnifiers. Improvements in reading rates were similar between groups. However, while no students in the large print group made substantial gains in reading comprehension, five of the eight students in the magnifier group did. Additionally, case studies conducted by Koenig et al. (1992) involving children with low vision documented that students' reading rates of regular print with optical aids were comparable or superior to reading rates of large print alone. In these case studies, participants reported more positive appraisals of optical aids than large print. The findings of these comparative studies have been corroborated by teacher reports that students who used optical devices achieved higher reading levels than students who used large print materials (Corn 1990).

Researchers concerned with the lack of consistent benefits from use of large print have examined how elements of print appearance in large print documents may affect reading abilities. In the previously discussed study, which evaluated the impact of text size on a computer screens, reading response times and error rates were found to covary with changes in the print's contrast and polarity (Bangor 1998). In another study, increased letter spacing was associated with improved reading speed and decreased minimum font size required by most participants with low vision (McLeish 2007). Also, in research with typically developing children, increased letter spacing led to more improvements in word identification and reading rate than did increased letter size (Hughes and Wilkins 2002).

Despite mixed findings about the benefits of large print text, many individuals with low vision use large print resources. In a survey of adults with low vision in Greece, 28 % reported using large print text "a lot," 9 % used it "quite a lot," while 55 % reported that they never used large print materials (Goudiras et al. 2009). Access to large print documents likely plays a role in the utilization of these resources in schools. In the United States, availability of large print textbooks in schools differs from state to state and district to district (Emerson et al. 2006). Issues such as funding and overall state resources for people with VI and blindness affect availability. For example, some states receive greater quantities of volunteered APH resources and some districts allot more money for textbook purchases. Also, due to production issues (e.g., lack of personnel, insufficient use of technology) large print texts are frequently delivered in an untimely manner and/or may not be available in an individual's needed font size.

Typoscopes. Typoscopes, also called writing guides, are non-optical devices typically made of dark cardboard, plastic, or metal, with cutout spaces that are overlaid lines of writing (AFB 2013h). Although some are specifically designed for writing, the guides are often used to assist students with low vision in reading (Lueck and Heinze 2004). Typoscopes may reduce glare and support readers' scanning across a page and shifting to the beginning of a new line. Typcoscopes may also reduce the minimum print size individuals need to discriminate between letters (Collins 2000).

Although there is limited research on the effectiveness of typoscopes for improving reading, some data suggest they can be helpful. In one study, low vision rehabilitation patients who reported seeing text as "jumbled" or "muddled" were given typoscopes with adjustable windows. Sixty percent of patients initially reported that typoscopes were helpful. Follow up after a year revealed 30 % of patients still used typoscopes on a regular basis and 50 % no longer experienced text as "jumbled" when not using a typoscope (Collins 2000). In another study, students with low vision underwent treatment that included use of reading stands, typoscopes, direct illumination, and/or large print materials (Shaaban et al. 2009). While data were not disaggregated by the type of low vision aids prescribed, the overall improvement in distance and near visual acuity task performance was statistically significant and 76 % of patients reported being satisfied with their low vision aids.

Reading stands. Book or reading stands are display supports that may reduce the physical stress or fatigue experienced by readers with VI who are prone to hold reading materials close or bend over surfaces to view text (Presley and D'Andrea 2009; AFB 2013f). Stands may also be helpful for readers of Braille (Presley and D'Andrea 2009). Varieties of stands are commercially available in portable, desktop, and floor models, and can also be fashioned out of common materials such as a closed, three-ring binder. The selection of an appropriate size and type of stand should be based on the needs of the individual.

The efficacy research which addresses reading stand use is limited. In the previously mentioned study by Shaaban et al. (2009), treatment packages for students with low vision included reading stands. As described above, treatment resulted in improvements in distance and near visual acuity task performance and satisfaction with treatment in 76 % of patients. Also, Gothwal and Herse (2000) analyzed the records of 220 children who received services at a low vision center in India and found reading stands were used in 6 % of treatments and were found acceptable by both parents and children.

Lamps. Improving lighting can be an effective way to make reading tasks easier for individuals with low vision (AFB 2013b; Bowers et al. 2001). Differences in vision profiles warrant careful selection of lighting to match individuals' needs (AFB 2013b). Any of a variety of common reading lamp bulbs, such as high-wattage, natural light (total-spectrum), compact fluorescent (CFLs), incandescent, and combinations of CFLs and incandescents may be effective reading aids when focused on reading materials. Research which compares bulbs' effects on reading performance in people with low vision has found no one bulb type stands out as superior (Eperjesi et al. 2007). Effects of a variety of bulbs were found to be statistically similar when results are aggregated across individuals. A large number of commercially available lamps have been designed for individuals with low vision to use for a variety of tasks, including reading (Gerritsen 2001). Popular lamps include variations of the OttLite, a total-spectrum lamp which has bright natural-appearing light, the Reizen Low Vision Floor Lamp, which uses an incandescent bulb that produces minimal glare and a warm hue, and the FD-100 halogen table lamp, which produces strong brightness.

Research suggests lighting enhancements can improve students' reading performance. For example, in a study of individuals with low vision, participants' visual acuity, minimum-required print size, and reading rate all improved at levels of illumination higher than participants' identified illumination preference at the study outset (Bowers et al. 2001). The authors of the study recommended that individual assessments for optimal lighting should consider objective measures of reading ability in addition to subjective ratings of visual comfort and lighting preference.

Despite the potential benefits, many people with VI do not strategically use lighting to improve their reading. In a study of typical reading environments of individuals with VI, 10 % of the reading places used by participants were found to have very high, adequate illumination and 63 % were found to have low, inadequate illumination (Lindner et al. 2001). Single, ceiling light sources were predominant in 60 % of reading locations and additional lights were only present in 40 % of locations.

Lens-based magnification aids. Lens-based magnifiers, such as telescopes and hand-held magnifiers, are task-specific optical aids that enlarge images and allow greater perception in users (Cline et al. 1997; Bowers et al. 2001). In contrast to regular glasses, which are often designed to maximize vision across a variety of contexts and activities, these magnifiers are prescribed for specific activities based on the user's context-related needs. Generally, lens-based magnification aids can be grouped into two categories: near-viewing optical aids and distant-viewing optical aids.

Near-viewing optical aids are used in tasks performed within arm's length, such as reading, writing, drawing, and sewing. Near-view optical aids include stand magnifiers, hand-held magnifiers, and magnifying reading glasses. Each of these aids involves a separate set of utilities and limitations. For example, hand-held and stand magnifiers may be commonly used by students with a variety of visual acuities and visual fields, while each pair of magnifying reading glasses are only useful to students with a particular visual acuity and visual field combination. Stand magnifiers are particularly useful for students with poor motor control due to their fixed position, however, for the same reason, they may be inappropriate for viewing some objects, such as large books. Hand-held magnifiers offer great flexibility in terms of holding distance and location, but the requirement of holding a steady position for reading can lead to fatigue in hands, arms, and/or shoulder muscles.

Distant-viewing optical aids are used in tasks performed at distances greater than arm's length, such as reading a chalkboard, viewing another's skill demonstration, and watching a sporting event. Common distant-viewing optical aids include hand-held and spectacle-mounted telescopes. Similar to above, these aids involve separate utilities and limitations. Hand-held telescopes are highly portable and typically the least expensive. These devices are best for "spot" viewing, such as reading clocks and bus numbers. However, hand-held telescopes require moderate or better motor control and users must remain stationary. Spectacle-mounted telescopes do not require users to remain stationary and circumvent the need for hand coordination and stability. Although, these aids are typically permanently attached to eye glasses and are regarded as unaesthetic.

Research on use of lens-based magnification aids indicates they can improve students' reading rate and comprehension, and facilitate advancements in reading fluency (e.g., Corn 1990; Farmer and Morse 2007; Koenig et al. 1992). However, outcomes have been found to vary across individuals (e.g., Rosenthal and Williams 2000), which suggests identification of the device that will enable the highest levels of reading performance in a student requires trial runs, evaluations, and comparisons with each student.

Electronic magnification aids. As discussed above with regard to AT for pre-academic learning, electronic magnifiers are commonly termed electronic vision enhancement systems (EVES) and closed-circuit televisions (CCTV; Wolffsohn and Peterson 2003). Compared to lens-based magnification aids for reading, EVES may support more natural working distances, better posture, and longer durations and higher rates of reading, as well as protect against light loss (Harper et al. 1999; Mehr et al. 1973; Uslan Shen et al. 1996). However, comparative research has produced conflicting findings. Some work suggests use of lens-based magnification aids is associated with the highest reading outcomes (e.g., Goodrich et al. 1980; Harper et al. 1999), while other studies have found EVES to provide superior support (e.g., Goodrich and Kirby 2001; Stelmack et al. 1991; Watson et al. 1997). Further, research which compares various EVES devices has found outcomes to vary across individuals and devices (e.g., Lusk 2012; Ortiz et al. 1999; Peterson et al. 2003). Taken together, these findings underline the need to conduct evaluations with each individual student during trial runs with a variety of magnification aids before selecting a device.

Technologies that Engage Senses and Abilities Other than Sight

Braille reading materials. Learning to read Braille characters with fingers is a route to literacy that circumvents the limitations of VI and blindness. Braille codes have been created for many languages worldwide using the standard rectangular cell, which contains up to six dots in a 2 by 3 grid (Spungin 1990). Reading materials are typically available in 3 levels of encoding: Grade 1, in which words are fully spelled, Grade 2, which uses abbreviations and contractions, and Grade 3, which involves authors' personal and nonstandard shorthand. The IDEA legislation mandates provision of instruction in and use of Braille with students with VI and blindness unless assessment data suggests an alternative reading media is more appropriate for the student (IDEA 2004a).

Research on the instruction and reading of Braille has documented many positive outcomes, including higher educational achievement and self-esteem, and greater financial self-sufficiency (e.g., Ryles 1997; Schroeder 1996; Stephens 1989). Experts in Braille instruction have argued students in Braille literacy programs should receive between 1.5 and 2 h of literacy instruction per day, as this is the typical amount of time sighted students receive literacy instruction in primary grades (Rex et al. 1994; Koenig and Holbrook 2000). Evidence supports daily Braille literacy instruction. Ryles (1997) found students with legal blindness who received Braille literacy instruction four or five times per week attained significantly and substantially better literacy skills than comparable students who received infrequent instruction.

Braille translation software and computer printers. To convert typical reading or instructional materials to Braille, students with VI and blindness or their teachers can use Braille translation software and computer printers (Disabilities, Opportunities, Internetworking, and Technology Center [DOIT] 2013b; Taylor 2001). Braille translation software recognizes a variety of digital text file formats (e.g., MS Word, PDF, HTML, RTF) as well as allow manual entry of text. The programs convert text to Braille characters in the user-specified language code (e.g., Spanish, English) and encoding grade (i.e., 1 or 2). Common translation software includes Duxbury Braille Translator by Duxbury Systems and Braille 2000 by Computer Application Specialties. Such programs submit Braille character files to special Braille printers, known as embossers. These printers produce raised dot Braille characters on thick paper. Braille embossers vary greatly in price and features. For example, some embossers are capable of producing Braille on both sides of paper (i.e., interpoint Braille), while others print on single sides only. The speed of embossers can range from production of 10 characters to 800 characters per second. High-end embossers can cost over $80,000, while basic versions range between $1,500 and $2,000.

Refreshable braille display. Refreshable Braille displays enable tactual reading of text from computer screens (AFB 2013c). The devices receive output from screen readers (described far below) and produce lines of Braille characters with small pins that raise and lower as the user navigates a screen and encounters text. Refreshable Braille displays can be expensive, however, prices vary greatly based on device features (Braille Note Users 2012). Units differ in the number of refreshable characters (i.e., 20 to 80 Braille cells), note taking and file storage capabilities, compatibility with specific screen readers, input button arrangements, and screen navigational tools. Additionally, some devices only facilitate reading (e.g., PacMate by Freedom Scientific, Focus by Freedom Scientific, Alva by VisonCue), while others enable both reading and Braille input (i.e., note taking; e.g., BrailleNote by HumanWare, Braille Sense by HIMS, and PacMate Omni by Freedom Scientific).

Research on refreshable Braille displays suggests the devices have limitations related to text accessibility and efficiency of use (Kamei-Hannan 2008; Sodnik et al. 2012). Kamei-Hannan (2008) evaluated the accessibility of computer-based language and reading tests. Students who were able to independently operate the devices and associated screen readers (i.e., with speech output disabled) discovered 13 % of the language test questions could not be read due to punctuation (e.g., underlining) that was not translated to Braille. Additionally, the students were unable to comprehend 21 % of the reading test questions due to difficulties related to scrolling through long passages of text. Sodnik et al. (2012) compared use of a refreshable Braille display and screen reader with a novel auditory interface which produced spatially positioned synthetic speech. In observations of a series of reading and information recording tasks, the researchers found the average task completion time was substantially less when participants used the spatial auditory system (i.e., 3 min, 12 s) than when they used the refreshable braille display and screen reader (i.e., 8 min, 38 s). However, no significant differences were found regarding the accuracy of information recorded.

Some research has investigated the use and availability of refreshable screen displays. For example, in a survey of college disability support service coordinators, respondents reported refreshable braille displays were available on only 13.9 % of campuses (Michaels et al. 2002). In another survey of teachers of students with visually impairments and blindness, teachers reported that only 2 % of students used refreshable Braille displays (Abner and Lahm 2002). Authors have hypothesized that the high cost of the devices and the decreasing number of individuals who read Braille has limited the popularity of refreshable Braille displays (Chiang et al. 2005).

Audio format materials. Audio format reading materials enable easy access to content for students with VI and blindness. In recent years, the availability and accessibility of audio books and other reading materials has greatly increased (Majerus 2011). Students with VI and blindness have a variety of options for engaging with audio format reading materials. They may use (a) dedicated audio book players (e.g., Booksense by HIMS), (b) devices that display text and play audio (e.g., Victor Reader Stream by Humanware), (c) multipurpose audio devices (e.g., iPod by Apple), and (d) computer software (e.g., Easy Reader by Dolphin).

Research on audio format materials is limited to a single study. In interviews with students with VI and blindness, Adetoro (2012) found audio format materials were preferred over Braille reading materials by over half of the students due to ease of understanding and playback, and their teachers' ineptitude with Braille.

Screen and document reading software. When students' visual impairments are severe to the degree that they cannot read or cannot efficiently read printed materials or type on computer screens, screen and document reading software may be employed to support access to reading content (AFB 2013e). These softwares allow students to convert text on screens and in documents to synthetic speech (i.e., audio output). To do so, students use a variety of key strokes to undertake actions, such as move about text, read a sentence or paragraph, spell out a word, and identify the location of the cursor. Additionally, the programs allow students to control computer operating systems and applications. In place of the typical visual feedback regarding computer input (e.g., clicking an icon with a mouse cursor opens an on-screen application window), screen and document reading software provides audio feedback (e.g., verbal announcement that an application has opened). Most versions of screen and document reading software allow users to vary several qualities of the synthetic speech, including rate and pitch, as well as to choose from among a variety of language and region-specific accents (e.g., English with a British accent). Common screen and document reading software includes both operating system-based programs (e.g., Narrator for Microsoft Windows Operating Systems, Voiceover for Macintosh Operating Systems) and third-party applications (e.g., JAWS from Freedom Scientific, Kurzweil 3000 by Kurzweil Educational Systems). As mentioned above, some softwares are capable of transferring information to refreshable Braille displays. Additionally, screen and document reading software can grant students with VI and blindness access to printed materials following their scanning and processing with optical character recognition software (e.g., ABBYY FineReader by ABBYY).

Research suggests students with VI and blindness require extensive training and on-going support to independently use screen and document reading software (Earl and Leventhal 1999; Lazar et al. 2007; Leventhal and Earl 1997). For example, students must learn many key strokes for initiating software functions and maintain current knowledge of procedures for accessing new file types, new versions of document applications, and re-organized webpages. Students may also benefit from typing instruction and keyboards adapted for persons with VI and blindness. In survey research with users of screen and document readers with VI and blindness, Earl and Leventhal (1997, 1999) found that a majority of respondents had some form of difficulty with reading tasks attempted in Microsoft applications. They further found 40 % of their sample avoided particular tasks altogether due to the difficulties. Similarly, Lazar et al. (2007) found users of screen and document readers had high levels of frustration in response to confusing speech outputs, software crashes, and incompatibility between the software and various reading documents (e.g., PDF variations).

Assistive Technologies for Writing

Visual impairments and blindness potentiate a number of challenges to students in writing tasks involving typical, visual mediums, such as ink on paper or type on computer screens (AFB 2013d, h; Ponchillia and Ponchillia 1996). In these visual mediums, students with VI and blindness can experience difficulties in learning the mechanics of writing (e.g., punctuation, spelling), taking notes during classes, and engaging in the various phases of composing (e.g., prewriting, drafting, editing) due to limitations of their visual acuity, visual field, and functional use of vision. Below, we describe the variety of AT used to support students with VI and blindness in writing tasks. When possible, we also summarize research on use of the AT.

Technologies that Enhance Sight Capabilities

Paper and writing utensils that provide visual and tactile cues. Individuals with VI may have difficulty with a variety of skills required for writing by hand, such as spacing and placing letters, and following lines (Ponchillia and Ponchillia 1996). Specialized paper and writing utensils that provide sharp contrasts, thick markings, and tactile feedback may aid students' recognition of appropriate locations for writing, increase handwriting legibility (AFB 2013h; Ponchillia and Ponchillia 1996). Paper widely known as "bold-lined paper" has dark, wide lines that may improve recognition of intended writing locations via increased contrast and visual cues. Bold-lined paper, notebooks, and graph paper are available in a variety of colors and line spacing (Russotti et al. 2004). Thick, felt-tip markers (e.g., 20/20 by MaxiAids) are often used in conjunction with bold-lined paper (AFB 2013d). The markers similarly provide high levels of contrast and visual cues, and may support students' formation, placing, and spacing of characters. Individuals who need tactile support for writing by hand may benefit from "raised-line paper" and writing utensils that provide high levels of tactile feedback on writing execution (e.g., HighMark by MaxiAids, Thermalpens by Repro-Tronics; thick, lead, or graphite pencils).

Research on paper and writing utensils that provide visual and tactile cues is limited to one supportive study. A group of Indian researchers who investigated custom intervention packages for students with VI found 80 % of participants who received bold-lined paper and felt-tipped markers considered these particular supports were helpful (Khan et al. 2003).

Typoscopes. As described in the above section on AT for reading, typoscopes are devices typically made of dark cardboard, plastic, or metal, with cutout spaces that are overlaid writing spaces (AFB 2013h; Ponchillia and Ponchillia 1996). Typoscopes may help guide letter formation, spacing, and placement via provision of physical boundaries and contrast. The writing guides may be rigid in construction or flexible, allowing for formation of letters that descend below the interior edge of the typoscope when aligned with the writing line (e.g., "g" or "p"). Some authors suggest flexible typoscopes require greater skill with writing utensils for successful use (AFB 2013d). A variety of typoscopes are commercially available, including writing guides specifically designed for writing checks, letters, and signatures. Additionally, typoscopes may be made out of common materials, such as cardboard.

Technologies that Engage Senses and Abilities Other than Sight

Braille making devices. Students with VI and blindness can make Braille documents with a slate and stylus, Braille typewriters (i.e., Perkins Braillers), or computer systems including Braille embossers, screen and document readers, word processors, and/or Braille translation software (Caton 1991). Braille slates consist of two pieces of metal or plastic attached with a hinge. The front piece contains rows and columns of holes, grouped in Braille cell rectangles (i.e., 2 by 3 hole grids). The back piece contains rows and columns of slight depressions which align with the holes on the front piece when the hinge is closed. Users insert a piece of thick paper between the slate pieces, close the hinge, and then, starting from the right side and moving left, press the stylus (i.e., a blunted bradawl) into the slate's holes to create the raised dots of Braille characters. When finished, users remove the paper from the slate and turn it over to read the Braille characters pushed up from the back side of the paper. Perkins Braillers are manual typewriters that contain six keys, corresponding to the six dots in Braille code, as well as space, line space, and backspace keys. While Braillers are more efficient means of producing Braille characters than use of a slate and stylus, review of what one has written is less convenient. The consensus among teachers of students with VI and blindness is that instruction in Braille literacy should include training with the slate and stylus, beginning in grade 3 or 4, and instruction in use of typewriters, beginning in grades 1, 2, or 3 (Koenig and Holbrook 2000).

Voice recorders. In school settings where accuracy and speed of note taking or writing is important, students with VI and blindness may benefit from making audio voice recordings (e.g., using digital, tape, or other electronic devices; Attmore 1990). Digital voice recorders may also be useful for organizational purposes, such as recording assignments or appointments. A variety of commercially available devices combine voice recording features with word processors (e.g., AudioNote by Luminant Software), word prediction (e.g., Premier Predictor Pro by Premier Assistive Technology), and talking dictionaries (e.g., KeyAccess by Premier Assistive Technology). School districts commonly provide voice recording devices to students with VI and blindness as accommodations for classwork and tests (e.g., Beech 2010).

Speech-to-text software. As an alternative to use of writing utensils and keyboards, students with VI and blindness may prefer to use speech recognition/dictation software that translates speech to text (AFB 2013g). Common speech-to-text programs include Dragon NaturallySpeaking by Next Generation Technologies, MacSpeech Scribe by Nuance, and PlainTalk by Apple (Stefanik 2012). In addition to speech-to-text translation, these programs permit use of voice commands for functions such as opening, editing, and saving computer files. Given speech-to-text programs were not specifically designed for use with screen readers, users of both software types occasionally encounter compatibility problems. Supplemental software, such as J-Say by Next Generation Technologies, can resolve such problems (AbilityNet 2007).

The limited literature on speech-to-text software involves mixed depictions of its utility. Survey research conducted with college-level disability support specialists suggests students with VI and blindness widely and successfully use speech-to-text programs (Michaels et al. 2002). Seventy-three percent of respondents reported they provided the software to students and rated it as moderately to highly useful. However, in a study of use of speech-to-text software by novice, sighted users, researchers found participants had difficulty correcting translation errors and required greater lengths of time for composition compared to when they used keyboards (Karat et al. 1999). These results seem to indicate the development of proficiency with speech-to-text software requires training and practice. Further, Schneiderman (2000) suggested composition with the software involves greater cognitive demands than keyboard use and, thus, may not be appropriate for certain students due to age or disability status.

Text-to-speech software. Talking word processors may support spelling and composition in students with VI and blindness (e.g., Write: Outloud by Don Johnston, Intellitalk by IntelliTools, Read and Write Gold by TextHelp; Angelocci and Connors 2002; Erickson 2004; Nicohls 2013). Students may derive similar support from combined use of typical word processors and screen and document reading software (e.g., JAWS by Freedom Scientific, Kurzweil 3000 by Kurzweil Educational Systems). The talking word processors and screen and document reading software provide auditory review of words as they are typed and allow listening to previously typed text, thus enabling students' recognition of spelling errors (i.e., via the resulting incorrect pronunciation of words) and needs for revisions in compositions. Students with low vision may additionally benefit from the programs' flexibility regarding text size and color, background color, and word highlighting during typing and auditory review. Authors have identified compatibility problems between talking word processors and screen readers related to keystrokes, spelling alerts, and automatic spell checks (Angelocci and Connors 2002).

Spelling and grammar checking software. Students with VI and blindness may obtain support for spelling and grammar from a variety of software programs. Typical word processors, such as MS Word by Microsoft, may be configured to work in conjunction with the JAWS screen reader to detect spelling and grammar errors (Microsoft 2013). Several previously mentioned programs (e.g., Read and Write Gold, Kurzweil 3000, KeyAccess) offer audio output spelling and grammar checking features (Angelocci and Connors 2002). Also, talking dictionaries designed for students with VI and blindness are available as hand-held devices (e.g., Franklin Speaking Language Master Special Edition by Franklin Electronic Publishers) and screen reader-compatible software (e.g., English Talking Dictionary by Premier Assistive Technology).

Survey research with authors with blindness suggests students with VI and blindness stand to benefit from spelling and grammar support (Evans et al. 2003). Respondents in the study reported regular use of spelling and grammar checking software, and indicated needs for such support.

Assistive Technologies for Mathematics

Given that much of the language of mathematics relies on visual reference, learning mathematical concepts can be especially challenging for students with VI and blindness (Jan et al. 1977; Dick and Kubiak 1997). For example, concepts such as direction, quantity, and shape require substantially more cognitive processing when visualization is not possible. Textual and audio supports, such as Braille textbooks and talking calculators, can be useful in facilitating student's access to mathematics materials (Dick and Kubiak 1997), however, tactile support and haptic technology at times offer advantages in the promotion of concrete mathematical understandings in students with VI and blindness (Bussell 2003; Karshmer and Bledsoe 2002). We describe technologies in each of these areas below, and, to the extent possible, research that supports their use.

Technologies that Enhance Sight Capabilities

Interactive whiteboards. Promethean boards and SMART Boards are large-format, interactive whiteboards that display a computer image and allow users to write directly on the screen. There is some evidence that these devices provide specific advantages for students with VI, such as providing users access to the projected image on a screen replicated at their desk (Bosetti et al. 2011), or enlarging text, tables, and graphics that otherwise might not be visible (Scholastic 2013; Smarttech 2005). Moreover, students with light sensitivity are often able to interact with the SMART Board at close distances (Scholastic 2013). Drawing on student and teacher expertise, a recent Illinois State University project offered guidance for using interactive whiteboards with students with VI, such as allowing students to access information displayed on whiteboard screens via devices such as iPads and using the SMART Board to teach students to locate coordinates on a graph (Illinois State University 2012).

Adapted graph paper. As in other subject areas, access to mathematics texts and assessments can be enhanced through large print and graphics (Landau et al. 2003; Willingham et al. 1988). With respect to graphing in particular, given the small-sized boxes and light-colored lines often used for traditional graph paper, graphical items are often inaccessible to students with VI (Royal National Institute of the Blind [RNIB] 2011). Large, bold-lined, or high contrast graph paper may be useful in this regard, and magnifying glasses can be used to supplement mathematics texts (Dick and Kubiak 1997; Landau et al. 2003). This specialized graph paper can be used in combination with pushpins and corkboards, flexible wax strips or felt-tip markers that help to create graphical points, lines, curves, and figures (Dick and Kubiak 1997). In addition, tactile graph paper is available for students with blindness (RNIB 2011).

Technologies that Engage Senses and Abilities Other than Sight

Adapted calculators. A variety of standard and scientific calculators are available that offer modifications for students with VI and blindness, such as large keys, high contrast screens, and Braille input and output (Center for Assistive Technology and Environmental Access [CATEA] 2009). Many accessible calculators also provide auditory output. These talking calculators have been shown to increase computational accuracy and improve efficiency in solving mathematics problems for students with VI (Champion 1976/1977). A recent study of a voice input, speech output (VISO) calculator for use with high school students with VI demonstrated that the tool increased efficiency and fostered greater independence for completing computational problems (Bouck et al. 2011).

In addition to supporting math computational skills, scientific and graphing calculators that include Braille or tactile keyboards and offer auditory output or haptic (i.e., vibratory) feedback may facilitate the learning of more advanced mathematics concepts (CATEA 2009). Examples of calculators or programs that offer auditory support for graphing procedures include the Accessible Graphing Calculator (AGC) and the Sonification Sandbox (Osterhaus 2002; Walker and Lowey 2004). More recent software developments also provide tactile support for graphing and allow students with VI and blindness to convert mathematical data and graphs to tactile forms using a Braille or graphics embosser that connects to the calculator (e.g., the Orion TI-84 Plus; Orbit Research 2013). However, there is little, if any, empirical support for the use of these calculators (Bouck et al. 2011), and systematic study of how to create effective auditory graphics in particular is limited (Walker and Nees 2005). Additionally, both computational and scientific calculators for students with VI have significant limitations with respect to size, price, and availability (Bouck et al. 2011).

Abacus. The abacus is an inexpensive, mechanical tool which may help students with VI and blindness understand mathematical relationships in a non-visual format (Ferrell 2006). Although an abacus can facilitate the learning of foundational-level mathematics, such as addition, subtraction, multiplication, and division, as well as higher-level mathematics, including fractions and decimals, there is conflicting evidence related to its effectiveness with students with VI and blindness. For example, one study showed that an abacus training program improved the computational skills of students with blindness (Nolan and Morris 1964), while another demonstrated that mental calculation and Braille computation were more efficient and accurate than using an abacus (Kapperman 1974).

Math manipulatives. When presenting visual concepts to students with VI and blindness, hands-on experiences with manipulatives can support learning (Belcastro 1993; Dick and Kubiak 1997; La Voy 2009; Osterhaus 2011). Specialized manipulatives designed to meet the needs of students with vision-related disabilities, as well as manipulatives used in mathematics instruction of students without disabilities, may facilitate students' learning of math concepts such as number sense, addition, graphing, and geometry. In fact, the use of concrete mathematical aids is one of just a few evidence-based practices that can increase computation accuracy (Ferrell 2006). Specialized manipulatives may utilize Braille, the Nemeth mathematics code, raised tactile elements (e.g., shapes and textures) or three-dimensional geometric components (Van Scoy et al. 2005). Examples include Tack-Tiles, number blocks, number lines, rulers, dice, counting rods, and algebra tiles (e.g., Belcastro 1993; Bussell 2003; Karshmer and Farsi 2008).

Although a variety of mathematics manipulatives are available for students with VI and blindness, empirical evidence supporting their effectiveness is relatively limited. One small study with first-grade students with blindness demonstrated large effects of using specialized rods for teaching addition and subtraction (Belcastro 1993). The rods were marked with grooves and dimples representing different numbers. Another study, which documented similarly large effects, showed students with VI benefited from the use of a variety of tactile and high-color contrast manipulatives (La Voy 2009). Additionally, two studies focused on college-age students showed use of paper shapes for surfaces and slices of geometrical figures promoted understanding of two- and three-dimensional figures (Spindler 2006), and that cardboard and modeling clay facilitated the teaching of statistical concepts (Gibson and Darron 1999). It is important to note, however, that the integration of audio and haptic support when using manipulatives may better support the learning of math concepts than the use of manipulatives alone (Crossan and Brewster 2008). Despite their potential, mathematics manipulatives are not always provided to or readily available for teachers who work with students with VI and blindness (La Voy 2009).

Tactile graphics. Presentation of information with tactile graphics represents an alternative to visual illustration that draws on haptic perception (Gardner 1996). Several specialized technologies, as well as common crafts materials, can be used to create tactile graphics (DOIT 2013a; Jayant 2006). Specialized technologies include Braille embossers (e.g., The Phoenix embosser by Enabling Technologies), dedicated tactile graphics printers (e.g., the Tiger series by ViewPlus, the Tactile Image Enhancer by Repro-Tronics), tactile displays, and capsule or swell paper and heating devices. Braille embossers allow supplementation of tactile graphics with Braille text, however they are unable to produce high resolution graphics due to their exclusive production of raised dots. Dedicated tactile graphics printers can produce high resolution graphics, although they have limited capabilities to print Braille text. Tactile displays (e.g., the Dot View 2 by KGS) work with software programs (e.g., ChattyInfty by InftyReader Group) to create graphics with a matrix of pins that rise and fall to form shapes and Braille characters. While tactile displays offer the advantages of image scrolling, magnification, reduction, and real-time display, the devices are very expensive. Capsule and swell paper offer the advantage of compatibility with typical computer printers. After printing, the paper is passed through a heating device (e.g., Swell-Form Graphics Machine by American Thermoform Corporation, Picture in a Flash Tactile Graphic Maker by HumanWare) which causes the inked portions to swell and create a raised graphic. Prior to employing these printing methods, a variety of computer software programs can be used to design graphics. Programs that utilize scalable vector graphics, such as Corel Draw, Adobe Illustrator, and Microsoft Word and Powerpoint, are regarded as best for creating tactile graphics due to features which enable customization of line thickness (Van Geem 2012). If these specialized technologies are unavailable or inaccessible, common craft materials, such as glue guns, yarn, and aluminum foil can be fashioned into tactile graphics (Ryles and Bell 2009; Smith and Smothers 2012). Additionally, tactile graphic materials are commercially available in academic resource kits for students with VI and blindness.

Research on tactile graphics supports their use with students with VI and blindness. Evidence suggests students can interpret complex tactile graphics (Campbell 1997) and oral explanations improve their understandings of the illustrated concepts (Krufka and Barner 2006; Schoch 2011). In a comparison of raised line graphics and relief-based graphics, Krufka and Barner (2006) found that raised line graphics are associated with greater concept comprehension than relief-based graphics. In a study of student attitudes toward mathematics, researchers found use of tactile graphics can improve students' appraisals of mathematics courses (Rule et al. 2011). Despite the potential benefits, tactile graphics are frequently not employed. Survey research has found that under half of all teachers of students with VI use tactile graphics with their students (Rosenblum and Amato 2004). The infrequent use may be due to a lack of preparation among teachers to employ tactile graphics in instruction. For example, in a recent survey, 65 % of teachers of students with VI reported they needed more training in creating and teaching with tactile graphics (Rosenblum and Herzberg 2011).

Braille translation software for mathematics. Various computer hardware and software offer support for Braille users' study of mathematics (Cooper 2007; Jayant 2006). Braille representation of numbers and mathematical notations typically involves the Nemeth code. To produce mathematics documents in Nemeth code Braille characters or convert Braille documents for sighted readers, teachers of students with VI and blindness may wish to use translation software for mathematics. Relevant computer hardware and software involve a variety of different processes. Numbers and mathematical notations may be converted from sighted math codes in digital format (e.g., written in MS Word by Microsoft or Scientific Notebook by MacKichan Software) to Nemeth code Braille characters (e.g., with Duxbury Braille Translation or Megadots by Duxbury Systems) and then printed with Braille embossers. For users without sight, creation of sighted math codes and translation to Braille may be aided by screen readers and voice recognition software. Some embossers contain translation software and, thus, remove the need for intermediate translation. For example, the Tiger embosser by ViewPlus can produce Braille documents from files coded in MathType, the mathematics code used in MS Word. Also, OCR programs specifically designed to recognize mathematical expressions, such as InftyReader by InftyReader Group, can be used with translation software to convert scanned documents into Braille code for printing. Finally, users fluent in Braille and the Nemeth code may manually enter characters in Braille note-takers or Braille translation software for conversion into sighted math codes and printing for sighted readers.

Research related to Braille translation for mathematics has addressed the manual translation competencies of teachers of students with VI (DeMario 2000; Rosenblum and Herzberg 2011), the perceived utility of translation hardware and software (Rosenblum and Amato 2004), and the functionality of OCR systems

(Jayant 2006). DeMario (2000), Rosenblum and Herzberg (2011) surveyed teachers of students with VI regarding their self-appraised competencies in manual translation of Nemeth code. Teachers reported to DeMario (2000) that their translation competency decreased and their anxiety in response to translation tasks increased as the complexity of mathematical expressions increased. Rosenblum and Herzberg (2011) found 84 % of teachers in their sample rated their translations as excellent or good. However, two-thirds stated they would benefit from further training in translation for mathematics and 40 % identified themselves as needing additional training. Together, these findings indirectly support use of translation hardware and software as an alternative to manual translation. Survey research on the utility of translation software suggests teachers perceive the systems to have moderate usefulness, and only minor differences exist between the systems' utility (Rosenblum and Amato 2004). In contrast, Jayant (2006) found OCR approaches differ substantially in their functionality (Jayant 2006). The researcher compared use of the InftyReader program, a standard OCR system not specifically designed to recognize mathematical expressions, and use of the two OCR systems in combination, and found the combined use resulted in 15 % greater accuracy of translations.

Assistive Technologies for Science

Similar to the study of mathematics, science courses may present challenges to students with VI and blindness due to the centrality of visually and spatially depicted information (LiveScience 2013; Senge 1998). A variety of technology based supports may support science-related learning in students with VI and blindness. However, very little research has explored their effectiveness in promoting learning. Below, we describe the available technologies and the research that supports their use.

Three-dimensional models. A number of three-dimensional models produced for science courses may be of use in instruction of students with VI and blindness (National Association of Special Education Teachers 2013). Examples include models of human bodies and organs for anatomy lessons, molecule construction kits for chemistry lessons, and models of DNA strands made for biology lessons. Research investigating use of three-dimensional models of cells found that students with VI and blindness made significant gains in identification of cell components (Jones et al. 2006). Further, students reported high levels of interest in the models as instructional tools.

Tactile graphics. Tactile, graphic illustrations of concepts may support learning in science course in students with VI and blindness (Independence Science 2013b). As described above in the mathematics section, various printers, special paper, and material kits for producing tactile graphics are available commercially, and common craft materials, such as glue guns, yarn, and aluminum foil are also useful for creating tactile, graphic illustrations. Several material kits specifically intended for use in science courses are available from the company Independence Science.

Data collection aids. In recent years, Independence Science has released versions of a device called Talking LabQuest, which enables independent participation of students with VI and blindness in a variety of science experiments and learning experiences in field and laboratory settings (Independence Science 2013a; LiveScience 2013). The device is a hand-held, portable computer that includes 70 sensors to measure variables, such as pH, temperature, salinity, and motion. Students operate the device with buttons, the touch screen, or spoken directions. Via a software add-on, called Sci-Voice Access Software, the device provides real-time audio announcement of measurement outcomes. The software allows students to customize the language, pitch, rate, punctuation, and pronunciation of announcements. Additionally, data are stored for later review and analysis.

Personal computer-based laboratory equipment. After collecting data, students with VI and blindness can analyze their data with a program called Logger Pro, by Vernier Software and Technology, which is compatible with screen readers (Independence Science 2013a; Vernier Software and Technology, 2013). The software accepts input from the Talking LabQuest, as well as manual entry of data. Students can use Logger Pro to perform a large variety of analyses (e.g., gas chromatography analysis, data modeling with specified functions), as well as to produce custom graphs and tables.

Clinical and Academic Implications for Use of Assistive Technologies with Students with Visual Impairments and Blindness

Current research and consensus on practice have a number of implications regarding AT for students with VI and blindness. Below, we discuss implications related to assessment, AT selection, teaching and encouraging AT use, technology abandonment, and future research.

Assessment

Given the variety of assessments pertinent to the abilities and support needs of students with VI and blindness, due diligence in assessment necessitates collaboration among professionals from multiple disciplines (Faye 1996; Hyvarinen 2000; Koenig and Holbrook 1995; Topor and Erin 2000). At a minimum, assessment should involve a medical professional, who can examine the student's visual acuity and visual field, and a teacher of students with VI, who can perform a functional vision assessment and learning media assessment. The involvement of professionals from additional disciplines has the potential to increase the utility and extent of the information produced by assessment (Sadao and Robinson 2010; Van Hof and Looijestijn 1995). Organizers of assessments should consider including (a) primary care physicians, (b) pediatric neurologists, (c) opthalmologists, (d) optometrists, (e) certified low vision specialists, (f) teachers of students with VI, (g) other special educators, (h) general education teachers, (i) rehabilitation therapists or counselors, (j) orientation and mobility specialists, and (k) professionals with expertise in treatment of any comorbid disabilities (e.g., occupational therapist).

The value of accurate and valid assessment to subsequent intervention has been repeatedly established in educational and behavioral research (e.g., Al Otaiba 2011; Iwata et al. 1994) and is widely accepted by educational professionals (e.g., IDEA 2004c). As mentioned above, failure to fully identify and address individuals' needs during the AT assessment and selection process is associated with dissatisfaction with and abandonment of AT (Cook 1982; Zola 1982). It is thus safe to assume generation of accurate and valid assessment data facilitates provision of optimal support to students. The issue of accurate and valid assessment is most relevant to preschool age students or those with comorbid intellectual disabilities, multiple disabilities, or autism spectrum disorders (Bergwerk 2011; Chou et al. 2011; Committee on Practice and Ambulatory Medicine Section on Ophthalmology, American Association of Certified Orthoptists, American Association for Pediatric Ophthalmology and Strabismus, and American Academy of Ophthalmology 2003; Geddie et al. 2013; Hyvarinen 2000; Topor and Erin 2000; US Preventative Task Force 2011; Utely et al. 1983). For these students, assessment procedures may need adaptation to yield valid outcomes. Professionals engaged in assessment should consider the degree of fit between assessment procedures and the student's age and abilities other than vision, and contemplate alternative approaches. Consultation with the student's parents, teachers, and other caretakers, as well as other professionals who work with the student can lead to recognition of inappropriate procedures and suitable alternative approaches (Bergwerk 2011; Committee on Practice and Ambulatory Medicine Section on Ophthalmology et al. 2003; Topor and Erin 2000).

Selection of Assistive Technology

In the consideration of AT for a student, the literature suggests best practice comprises (a) matching AT to students' goals and needs, (b) involvement of representatives from multiple disciplines, (c) provision of complimentary supports, (d) initial and on-going evaluation of AT implementation outcomes, and (e) sensitivity to students' cultural norms and preferences. Given the purposes of AT for students with VI and blindness are to increase or improve their functional capabilities, support their education and development, and facilitate their independence

(Desch 2013; IDEA 2004c; Sadao and Robinson 2010), AT selected for a student should match their needs for support in functional tasks and enable attainment of goals for education and development (Bryant and Bryant 2003; Cook and Hussey 2002; Topor and Erin 2000). Professionals engaged in the selection of AT for a student may find it useful to augment assessment findings on the student's abilities and support needs with information on students', parents', teachers', and other caretakers' expectations and goals for the student's functioning. Doing so may involve interviews, review of Individualized Education Program documents for the student, or formal instruments, such as the Expectations for Visual Functioning (Corn and Webne 2001).

Given the diversity of technical expertise required for assessment and interpretation of data on the abilities and support needs of students with VI and blindness, the brainstorming of possible AT solutions may benefit from the involvement of representatives from multiple disciplines (Faye 1996; Hyvarinen 2000; Koenig and Holbrook 1995; Sadao and Robinson 2010; Topor and Erin 2000; Van Hof and Looijestijn 1995). For example, optometrists have unique expertise in refraction-based solutions (e.g., eyeglasses), certified low vision specialists and teachers of students with VI likely have unique expertise in non-optical aids for vision, and the student's teachers and parents likely have unique insights regarding the practicality of implementing various forms of AT. Further, the complementarity of AT selected for a student can be improved by including professionals from multiple disciplines (Hyvarinen 2000). For example, for certain students use of refractive magnifiers can problematically reduce the contrast of reading materials (Cline et al. 1997). Should a teacher suggest use of a magnifying glass due to its practicality, an optometrist could add the suggestion of outfitting the magnifying glass with a colored film that enhances the contrast of reading materials. Also, students with comorbid disabilities may require multiple, complementary supports (e.g., vision, head position, and posture supports for students with multiple disabilities; Friend 2011). In such cases, collaborations among professionals, such as optometrists, occupational therapists, and teachers are likely to lead to more effective and practically feasible solutions.

Conducting initial and on-going evaluations of the use of AT with students facilitates determination of the adequacy of a student's supports (Alberto and Troutman 2012; Bryant and Bryant 2003; Cook and Hussey 2002). Since no structured system exists for the selection of AT and implementation results vary from person to person, the process typically begins with educated guesses as to what would produce benefit for the student, based on review of assessment results and the professionals' prior experiences (Desch 2013). Evaluation of the adequacy of identified AT and related supports should follow this guesswork. The evaluation process should start with collection of baseline data on the student's present levels of functioning. Subsequently, data should be collected during test runs performed in all settings in which the student will use the AT, to confirm the AT and any additional supports provided are adequate. After making any adaptations to the support plan and performing additional test runs, on-going evaluations should be maintained to monitor the success of implementation and emergent needs of the student. Use of single-subject research design methodology (e.g., operational definitions of behavior, behavior counts, multiple baselines across settings) can promote objectivity in evaluations (Kennedy 2005).

A final set of issues to consider in the selection of AT for students with VI and blindness are their cultural norms and preferences (Sadao and Robinson 2010). Across culture groups, norms and preferences may vary with regard to visual behavior, play, care, and children's rights (e.g., Salend and Taylor 2002; Xie 2009). To respond to a student's culture and arrive at socially valid intervention plans, professionals should engage families and students in the processes of intervention plan development and implementation of AT.

Teaching and Encouraging Use of Assistive Technology

To encourage students' use of AT, professionals, parents, and other caregivers should (a) use evidence-based methods to teach and support skills for AT use, (b) include goals and objectives for AT use in the students' IEPs, (c) integrate intervention into students' preferred functional activities, and (d) provide complimentary services that support the students' AT use. Many forms of AT for students with VI and blindness require specific skills for successful use. On-going use of evidence-based methods for teaching and behavior support, such as direct instruction, practice with feedback, shaping, and reinforcement of success, provides the greatest likelihood students will acquire the requisite skills and maintain the related behaviors (Alberto and Troutman 2012; Archer and Hughes 2011; Sadao and Robinson 2010). To bolster efforts to teach skills for use of the AT, a student's IEP committee should include goals and objectives for AT use in his/her IEP (Geddie et al. 2013; Friend 2011; Presley 2010). The potential value of doing so derives from the committee's articulation of what successful implementation of the AT will include, commitment to on-going implementation and monitoring of outcomes, and delineation of responsibilities for adapting the intervention plan as necessary. Students' success in use of AT may be enhanced by integrating intervention into students' preferred functional activities (Topor et al. 2004; Lueck and Heinze 2004) and providing complimentary services (Cochrane et al. 2011; Ferrell 1996, 1985; Tavernier 1993; Topor and Erin 2000). Integration of intervention into preferred functional activities can facilitate the student's access of established and preferred reinforcers, which may lead to increased use of the AT in the activity context and beyond. Provision of complimentary services, such as medical treatment, behavioral optometry/vision instruction, adaptation of the physical environment, and orientation and mobility training, may enhance a student's visual functioning and improve outcomes of AT use, thereby enabling increased access to natural reinforcers for AT use.

Technology Abandonment

Roughly one-third of all recipients of AT have been found to abandon their devices (Phillips and Zhao 1993). As stated above, abandonment of AT is associated with reports that one's needs were not fully identified and addressed during the AT assessment and selection process (Cook 1982; Zola 1982). Frequently cited reasons for AT abandonment have specifically included complaints that (a) the AT did not enable satisfactory improvements in functioning, (b) use of the AT was inconvenient, awkward, and/or socially stigmatizing, and (c) the AT was not relevant to personal goals for improved functioning (Cook 1982; Day et al. 2001; Phillips and Zhao 1993; Zola 1982). Professionals may be able to decrease the likelihood of AT abandonment by making efforts during assessment, AT selection, and phases of teaching and supporting AT use. For example, to maximize the potential for improvements in functioning, professionals can (a) conduct initial evaluations of the AT's appropriateness and the student's functioning with the AT in all settings targeted for use prior to committing to implementation (Alberto and Troutman 2012; Bryant and Bryant 2003; Cook and Hussey 2002), (b) provide support for the student's use of the AT with fidelity to the plan established (e.g., in the student's IEP; Geddie et al. 2013; Friend 2011; Presley 2010), (c) conduct on-going evaluations of the AT's appropriateness and the student's functioning with the AT, and, if relevant, consider alternative forms of AT and/or additional training and support for use of the AT (Alberto and Troutman 2012; Bryant and Bryant 2003; Cook and Hussey 2002), and (d) provide treatment for any comorbid disabilities or disorders to attenuate their impact on the student's functionality and use of the AT (Levack et al. 1994). To reduce any inconvenience, awkwardness, or social stigma involved in AT use, professionals can (a) monitor these factors in initial and on-going evaluations of the student's functioning with the AT, and (b) consult with the student and his/her family and teachers regarding the potential for these experiences prior to implementing the AT (Day et al. 2001; Scherer 1998b). Also, to improve students' perception of AT as relevant to their personal goals for improved functioning, professionals can consult with the student and his/her family prior to implementing the AT.

Authors have published several instruments that formalize these preventative practices. The Assistive Technology Device Predisposition Assessment (Scherer 1998a; Scherer and Craddock 2002) structures the gathering of information on students' personal goals and, for a particular AT device, the potential for improved functioning, inconvenience, awkwardness, and social stigma. Tools for assessing students' satisfaction with AT after beginning implementation include the Quebec User Evaluation of Satifaction with Assistive Technology (Demers et al. 2002) and the Psychosocial Impact of Assistive Devices Scale (Day et al. 2002; Jutai et al. 2005). Additionally, useful information may be generated by the vision-specific quality of life measure Impact of Vision Impairment on Children (Cochrane et al. 2011).

Areas for Future Research

Areas for future research on AT and students with VI and blindness include (a) the reliability and validity of AT assessment methods' outcomes, (b) the efficacy of various AT in improving students' functioning, (c) students' preferences for particular AT supports, (d) the impact of provision of complimentary supports on visual functioning and related behavior (e.g., vision instruction, environmental modifications), (e) the effects of instruction on AT use, and (f) circumstances that influence the fidelity of AT interventions' implementation and the effectiveness of interventions. Given the paucity of research in these areas and the value of research findings to optimizing the education and development of students (IDEA 2004c), there is a great need for continued work in these areas.

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Chapter 6
Assistive Technology for People with Autism Spectrum Disorders

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Introduction

The term "assistive technology" refers to any device or piece of equipment that facilitates teaching new skills, augments existing skills, or otherwise reduces the impact of disability on daily functioning (Bryant et al. 2010; Reichle et al. 2011). The technology involved may be sophisticated "high-tech" or relatively simple "low-tech" (Shane et al. 2012). For example, an individual could receive intervention from a robot therapist (e.g., Vanderborght et al. 2012) or exchange laminated picture cards as a form of communication (e.g., Ganz et al. 2012b). Regardless of the function or complexity of the device or equipment, the purpose of assistive technology is to improve the user's quality of life via increased independence.

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Individuals with autistic disorder and Asperger's syndrome (referred to collectively as people with autism spectrum disorder [ASD]) are often recipients of assistive technology due to obstacles arising from the symptoms and the learning and behavioral characteristics associated with ASD (Francis et al. 2009; Hess et al. 2008; Mechling 2011; Shane et al. 2012). For example, assistive technology designed to provide alternative modes of communication (e.g., speech-generating devices) or to prompt social initiations (e.g., tactile pager prompts) might be used to ameliorate the communication and social deficits experienced by people with ASD (American Psychiatric Association [DSM-IV-TR] 2000; Mirenda 2001). Similarly, restrictive and repetitive patterns of behavior and interests may be addressed using self-management strategies supported by technology. For example, an iPad might be used to deliver a video modeling intervention designed to ease transitions across activities or environments for children with ASD in school (Cihak et al. 2010). In addition to addressing the diagnostic symptoms of ASD (i.e., communication and social deficits and repetitive patterns of behavior and interests), assistive technology might also be used to mitigate many of the other impediments often associated with ASD including those arising from intellectual disability (Matson and Shoemaker 2009), delayed or abnormal development of motor behaviors (Green et al. 2008), and problem behavior (e.g., property destruction, aggression, and self-injury) (McTiernan et al. 2011).

This chapter provides a review and discussion of research involving the use of assistive technology in the education and treatment of individuals with ASD. Specifically, research involving assistive technology to support or improve the: (a) communication skills, (b) social and emotional skills, and (c) daily living and other adaptive skills of people with ASD. For each of these areas, the studies are analyzed and summarized in terms of participant characteristics, dependent variables, intervention components, and outcomes. The aim of these summaries is to guide practitioners and researchers in their efforts to make effective use of assistive technology for improving the quality of life of people with ASD.

Assistive Technology for Communication

People with ASD may experience a wide array of deficits in communication (American Psychiatric Association 2000; Howlin 2003). People with autism, for example, may have a very limited spoken repertoire with as many as 61 % failing to develop speech altogether (Weitz 1997). Whereas people with Asperger's syndrome will often develop good speech skills, they may still struggle to communicate effectively due, in part, to perseveration on preferred conversation topics (e.g., frequent discussion of trains, the plots of movies, or other topics), unusual reactions to social cues from conversation partners (e.g., misinterpreting facial expressions), or anxiety-related to social situations (Scheuermann and Webber 2002). Further, individuals with ASD may engage in a number of stereotypies that can impede communication, for example, echolalia (i.e., verbatim repeating of someone else's words) involves speech but often might appear to lack communicative intent (Sigafoos et al. 2007a, b, c).

Deficits in communication have been associated with an increased likelihood of developing problem behavior (e.g., tantrums) and may hinder employment, inclusion within the community, and overall ratings of quality of life (National Research Council 2001). For example, Burgress and Turkstra (2010) administered the American Speech-Language-Hearing Association's Quality of Communication Life Scale (Paul et al. 2004) to a group of 15 typically developing adolescents and to a group of 14 adolescents with Asperger's syndrome or high functioning (i.e., individuals with IQ higher than 80) autism. Even though the communication deficits experienced by this sample of the ASD population were notably less severe than those experienced by many people with an ASD diagnosis, the results suggested that people with high functioning autism or Asperger's syndrome rate their quality of life lower than typical developing peers due to their deficits in communication and social interaction skills.

Given the prevalence and potential negative impact of communication impairment, individuals with ASD are obvious candidates for assistive technology designed to support communication. Assistive technology used to support communication may be referred to as aided augmentative and alternative communication (AAC) (Sigafoos and Drasgow 2001). Aided AAC systems include high-tech electronic devices such as speech generating devices (SGD) and more low-tech materials, such as pictures or symbols that can be pointed to, affixed to a board, or exchanged with a communication partner (e.g., Bondy and Frost 2002). Most aided AAC systems involve visual cues (e.g., pictures or symbols) that are intended to build on the visual processing ability thought to be well developed in many people with ASD (Mirenda 2001; Shane et al. 2012). Unaided AAC systems (e.g., sign language) are not typically considered to be assistive technology because there is no external device or piece of equipment involved. For example, individuals with ASD might use gestures (e.g., head nod), eye gaze, hand leading, and other motor behaviors as a means to communicate (Drasgow and Halle 1995) and, in some cases, these prelinguistic behaviors can be expanded upon to improve communication without the need of assistive technology (e.g., Valentino and Shillingsburg 2011).

The specific AAC modality selected for an individual likely influences the person's success in communicating (Tincani 2004; Zangari et al. 1994) and the decision to use either an aided or unaided AAC system is influenced by a number of factors. Sigafoos and Drasgow (2001), for example, suggested that physical impairments should be assessed to determine if some forms of AAC might be impractical. For example, some individuals with ASD may have motor impairments that could render sign language too difficult to learn. In such cases an aided AAC, that requires less manual dexterity (e.g., activation of a speech generating device), might be indicated. Similarly, the ability to imitate the motor behavior of another person has also been suggested as a prerequisite skill for sign language training that may not be required for using other types of aided AAC (Bondy and Frost 2002).

Tincani (2004) assessed the importance of considering motor imitation skills when selecting between sign language and the Picture Exchange Communication System (PECS). The motor imitation skills of two elementary school age participants with autism were assessed by asking them each to imitate 27 different hand, arm, and finger movements that are necessary to form many common signs. One participant was able to imitate only 43 % of the movements and the other participant was able to imitate 76 %. An alternating treatment design was then used to compare the number of independent requests (mands) and word vocalizations that occurred during a sign language condition and a PECS condition. In both conditions training involved the participant being shown a preferred item, prompted to request that item either with a sign or picture exchange, fading prompts over time, and reinforcing requests with access to the requested item. The participant who performed better on the imitation assessment produced a higher percentage of independent requests during the sign language condition while the other participant produced more during the PECS condition. These results highlight the importance of considering motor imitation prior to selecting an AAC modality.

One of the most important considerations when selecting between different AAC modalities is whether or not research has demonstrated the effectiveness of a specific modality. In an effort to elucidate the research base, Table 6.1 provides summaries of 10 recent literature reviews focused on aided AAC for people with ASD. This table was created by searching the electronic databases ERIC and PsychINFO using key terms related to ASD, assistive technology, and communication. Literature reviews focused on this topic that were published in peer-reviewed English language journals within the last 10 years (2003–2013) were included in the table. Only reviews, as opposed to individual intervention studies, were included due to the large number of research papers published in this area. The reviews summarized in Table 6.1 suggest that the three most common approaches to supporting communication using assistive technology are speech generating devices (SGD), picture exchange communication systems (PECS), and computer-based instruction (CBI) (e.g., Ganz et al. 2012b; Ramdoss et al. 2011; Schlosser and Wendt 2008; van der Meer and Rispoli 2010). Each of these forms of assistive technology is discussed in more detail.

Speech-Generating Devices. A SGD (also referred to as a Voice Output Communication Aid (VOCA)) is a portable device that contains one or more panels or switches that when depressed will activate pre-recorded digitized or synthesized speech output. These devices range in complexity from a single panel/switch that plays one message to multiswitch devices that can serve numerous communicative functions including requesting, commenting, and greeting. Pictures or symbols on the device indicate to the user what message will be played if a specific switch is activated. For example, a picture of a favorite toy may be used to indicate that the message “May I have my toy please?” will be played if the corresponding panel on the SGD is activated.

There are several potential advantages to using SGD to support communication. First, they are often highly portable (Mechling 2011). For example, when the correct software application is installed, a handheld iPod or iPad can be used as a

Table 6.1 Summary of reviews on communication interventions involving assistive technology for people with autism spectrum disorders

Citation	Review description and methodology	Findings and conclusions
Ganz et al. (2012a)	Meta-analysis of 13 single-subject research studies involving PECS and individuals with ASD; Utilized systematic search and coding procedures; Calculated ES[a] using IRD[b]	PECS is a promising intervention; ES was greatest when used as part of FCT[c] and with preschool children with autism; people who advanced through the most PECS phases had the best communication outcomes
Ganz et al. (2012b)	Meta-analysis of 24 single-subject research studies on aided AAC systems with individuals with ASD; Utilized systematic search and coding procedures; Calculated ES using IRD	Large ES on targeted behavioral outcomes were reported for aided AAC interventions; ES was greater for communication than for other targeted outcomes; PECS and SGD had larger ES than other picture-based communication systems
Ganz et al. (2011)	Meta-analysis of 24 single-subject research studies on aided AAC systems with individuals with ASD; Utilized systematic search and coding procedures; Calculated ES using IRD	All ES were rated as moderate or better; largest ES were associated with people with ASD and no other comorbid disorder and preschool age participant
Ganz et al. (in press)	Meta-analysis of 35 single-subject research studies on aided AAC systems with individuals with ASD; Utilized systematic search and coding procedures; Calculated ES using IRD	Largest ES were associated with general education classrooms; PECS and SGD were associated with larger ES than other picture AAC systems; SGD had larger ES than PECS for problem behavior treatment
Ramdoss et al. (2011a)	Systematic review of 10 studies using CBI to teach communication skills to children with ASD; Search parameters, coding procedures and inclusion criteria were described and checked by multiple co-authors; Calculated ES using NAP[d]	CBI is a promising instructional approach for communication skills but should not yet be classified as research-based due to a limited number of conclusive studies
Schlosser and Wendt (2008)	Systematic review of nine single-subject design studies and two group design studies with the aim to determine the effects of ACC on speech production in children with ASD; Search parameters, coding procedures and inclusion criteria were described and checked by multiple co-authors; Calculated ES using PND (single-subject designs) and Cohen's *d* and Hedge's *g* (group designs)	AAC interventions do not prevent the development of speech in children with ASD; Most studies reported increases in speech during or following AAC intervention, but ES for increasing speech were modest

(continued)

Table 6.1 (continued)

Citation	Review description and methodology	Findings and conclusions
Sulzer-Azaroff et al. (2009)	Systematic review of 34 intervention studies involving PECS and individuals with ASD; Search procedures and inclusion criteria were described and checked by multiple co-authors	PECS resulted in improved communication for the vast majority of 386 participants involved across studies (most where male children with autism); PECS was associated with an increase in speech and social approaching in several studies; Children taught to request with PECS performed equal to or better than those taught with other AAC interventions
Tincani and Devis (2011)	Meta-analysis of 16 single-participant studies involving PECS and people with developmental disabilities (majority with ASD); Search parameters, coding procedures and inclusion criteria were described and checked by multiple co-authors; Calculated ES using PND[e]	PECS had a moderate ES for teaching requesting (PND = 80) for 41 participants to phase IV of PECS; More requesting was identified in participants with developmental disabilities other than ASD and when PECS was evaluated in only one environment; for participants who engaged in speech PECS appeared to have increased the amount of speech produced
van der Meer and Rispoli (2010)	Systematic review of 23 single-subject research studies involving SGD for children with autism; Search parameters, coding procedures and inclusion criteria were described and checked by multiple co-authors	Positive outcomes were reported in 86 % of the studies suggesting that SGDs offer viable means of communicating for children with autism; Majority of research targeted requesting; Additional research regarding more complex multifunction communication, maintenance and generalization is warranted
van der Meer et al. (2011)	Systematic review of seven single-subject research that involved assessing the preference of people with developmental disabilities (including ASD) for specific AAC options. Search parameters, coding procedures and inclusion criteria were described and checked by multiple co-authors	Across the reviewed studies, 55 % of participants did indicate a preference for one type of AAC over another. Of those, 68 % of participants preferred SGD and 33 % preferred picture-based communication systems. Incorporating choice between AAC options is thought to enable increased self-determination

[a] Effect size
[b] Improvement rate difference
[c] Functional communication training
[d] Nonoverlap of all pairs
[e] Percentage of nonoverlapping data

SGD device, and the ubiquity of such handheld devices among the typically developing population might also help reduce the stigmatization of using assistive technology for communication (Kagohara et al. 2013). Second, because electronic speech is produced, communication attempts may be more easily understood by most communication partners than more ambiguous forms of AAC such as sign language (Mirenda 2001). Finally, the SGD models the correct spoken message during moments when the person is motivated to communicate and some studies have demonstrated that using a SGD may lead to the acquisition of spoken communication (Schlosser and Wendt 2008).

SGDs can also be used as part of a treatment package to reduce problem behavior. For example, Franco (2009) taught a 7-year-old boy with autism who had no spoken language and engaged in high rates of vocal stereotypy (i.e., repeating the vowel sound "eeee") to use a SGD. The SGD used in the study was a GoTalk© with 12 buttons and was chosen because the child's family indicated a preference for it over other options due to its low cost (i.e., less than $300 USD) and relative simplicity. Prior to intervention, a functional analysis (Iwata 1982/1994) revealed that the child's vocal stereotypy was functioning as a form of communication. Specifically, the child would produce the "eeee" sound as a means to request a break from school work and to request access to specific toys and activities. The SGD was programmed to serve the same communicative functions as the vocal stereotypy by recording messages that requested preferred items or activities and breaks from work across different environments. For example, in the classroom, a symbol on the SGD was available for requesting a break from school work; in the gymnasium symbols were available for requesting a break and gaining access to specific activities (e.g., scooter board) and on the playground symbols were programmed for requesting specific play materials or activities (e.g., swing). The child was taught to discriminate between the multiple options on the SGD using a most-to-least prompting hierarchy and differential reinforcement (Duker et al. 2004). Probably because selecting the symbols on the SGD was intended to serve the same communicative functions as the vocal stereotypy and was a more efficient way to communicate, vocal stereotypy was nearly eliminated when the child began independently using the SGD. This study demonstrated the potential of a SGD to be used across multiple settings, for a variety of communicative functions, and to reduce problem behavior when the communicative function of the SGD is matched to that of problem behavior (c.f., Carr and Durand 1985).

A recent systematic review conducted by van der Meer and Rispoli (2010) focused on communication interventions involving SGD and children (<18 years old) with ASD (see Table 6.1). The review identified 23 studies involving a total of 51 participants. Of those participants, 67 % were diagnosed with autism and the remainder where diagnosed with either Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) or simply described as having an ASD without providing further detail. The review utilized a thorough systematic search involving multiple electronic databases, ancestry searches, and hand searches; however, no studies involving participants with Asperger's syndrome were identified for inclusion in the review. This is perhaps due to the fact that people with Asperger's syndrome develop speech and SGDs might be seen as unnecessary. A variety of different communication skills were enabled through the use of SGDs, with the majority of studies (70 %) focused on using the device to request preferred items, food, or activities. The remainder of the studies utilized SGDs for commenting (e.g., starting a conversation), answering questions (e.g., selecting between "yes" and "no"), and reducing vocal stereotypy. The majority of the reviewed studies employed single-case experimental designs and demonstrated clear intervention results. However, it was also noted that there was a lack of randomized control trials. As such, there appears to be a need for more research involving larger groups of participants and demonstrating the utility of SGDs for more complex communication needs, such as sustaining a conversation and asking questions.

The Picture Exchange Communication System (*PECS*). PECS involves teaching the person with ASD to communicate via handing their partner a picture or symbol card depicting their communicative intent (Bondy and Frost 2002). People learn to communicate with PECS by progressing through six phases that involve increasingly complex forms of communication. The first phase involves teaching a request for a preferred tangible (e.g., toy or food). The person is physically prompted to pick up a picture of the item (e.g., candy) and hand it to their partner. The communicative partner then verbally acknowledges the request (e.g., "You want candy") and immediately reinforces the picture exchange with the object that was requested (e.g., gives the child candy). In the second phase the person is taught to remove the picture from a display board and bring the picture to the communication partner from a greater distance. During the third phase, the person is taught to select pictures from an array of multiple pictures on a display board and to visually discriminate target pictures from other pictures (for a description of training picture-item correspondence see Sigafoos et al. 2007a, b, c). In the fourth phase the picture cards are combined with other cards containing sentence fragments (also called carrier phrases). For example, a child with ASD might select a card with a picture of candy and another card with the carrier phrase "I want" written on it. Pictorial representations of carrier phrases may also be used for individuals who are not able to read. During this phase, when the communication partner receives the sentence strip with two cards indicating the child wants candy, the communication partner will first read the carrier phrase and then pause to allow the child the opportunity to vocalize the request. If the child does not vocalize the request, the item is still provided. In the fifth and sixth phase, the person is taught to respond to questions (e.g., "What do you want?" or "What do you see?") using the picture cards.

In addition to increases in picture exchange communication, PECS has also been shown to be associated with an increase in spoken communication in children with ASD (e.g., Anderson et al. 2007; Charlop-Christy et al. 2002; Ganz and Simpson 2004; Ganz et al. 2008; Jurgens et al. 2009; Tincani 2004; Tincani et al. 2006; Yoder and Stone 2006). For example, Yoder and Stone (2006) randomly assigned 36 children to either a PECS or Responsive Prelinguistic Milieu Teaching (RPMT) condition, and found that PECS resulted in a significantly greater increase in frequency of speech and in the variety of words used after 6 months of intervention. Currently, the mechanism by which PECS increases speech remains unclear (Preston and Carter 2009). However, Yoder and Stone hypothesize why speech may emerge during PECS even though speech is not directly targeted. First, PECS requires coordinated or joint attention between the person with ASD and their communicative partner. This coordinated attention has been shown to elicit linguistic input from caregivers (e.g., "I see you want candy"), and this input may serve as a model for speech (e.g., Yoder and Warren 1998). Second, in the final phases of PECS, the instructor uses a cloze procedure (e.g., "I want _____") as a prompt for the child to engage in picture exchange. This procedure may also be an effective prompt for speech. Third, PECS encourages parents to use linguistic mapping (i.e., verbally narrating the events happening around the person), which may serve as a model of speech. Future research involving a component analysis is needed in order to determine the precise mechanism by which PECS increases spoken communication.

Ganz et al. (2012a) conducted a meta-analysis of 13 PECS intervention studies involving people with ASD. Only studies using single-case experimental designs were included in the review. A wide range of effect sizes ((ES) range, –0.51–0.95) was reported suggesting that PECS is very effective but outcomes hinge on additional factors. Specifically, PECS was found to be more beneficial for preschool age participants than elementary or secondary age participants and for participants with autism without any other comorbid developmental or intellectual disability diagnosis. Additionally, the effects on targeted dependent variables (i.e., picture exchange) and effects on collateral "untargeted" dependent variables (i.e., problem behavior and speech production) were analyzed separately and compared. Results indicate that the largest ES are associated with targeted dependent variables and that outcomes for reducing problem behavior and increasing speech are highly variable but promising. Ganz and colleagues recommend cautious interpretation; specifically, PECS does not hinder speech production or increase problem behavior but improvements in those variables are inconsistent across studies. Additional research is necessary to determine the factors that predict improvements in those variables following PECS training. This conclusion is aligned with Schlosser and Wendt's (2008) review that did include studies with group designs in the analysis (e.g., Yoder and Stone 2006).

Computer-Based Instruction. Recent advances in technology have increased the versatility and reduced the financial cost of computers. Computers are now commonplace in schools and are often used to deliver instruction to students with and without disabilities (e.g., Inan et al. 2010; Ramdoss et al. 2011a). Computers can be considered assistive technology when they are used to deliver or supplement intervention for people with disability. Although handheld computers (e.g., iPads) can be programmed for use as a SGD (Kagohara et al. 2013; Mechling 2011), the use of computers does not involve CBI per se. CBI differs from the aided AAC systems (e.g., SGD) because the computer does not usually travel with the individual to function as a communication modality. Rather, the computer is used to teach some skill that, once acquired, improves an individual's communication even though the computer may not be present. For example, Simpson et al. (2004) used CBI to teach four children with autism to greet their peers. The software program HyperStudio 3.2 was used to present a series of pictures, written instructions, synthesized speech, and video model examples. Participants accessed the computer in their special education classroom for 45 min for 24 school days to work through the programmed curriculum. A multiple baseline across participants design demonstrated an increase in spoken greetings for all participants during school activities in which the computer was not present (e.g., craft time and academic instruction).

There are several potential advantages to using CBI to teach people with ASD communication skills. Specifically, a computer is very consistent and predictable and may therefore be a preferred medium for instructional delivery for people with ASD who prefer routines and managed expectations (Ramdoss et al. 2011a). Further, computers can provide a one-to-one instructional format that reduces distractions and control for autism-specific learning characteristics such as stimulus overselectivity (Lovaas et al. 1979). Finally, computers can efficiently and accurately implement complex reinforcement schedules, provide and fade prompts, and collect data on participant responses simultaneously while demanding less time and attention from a teacher or therapist (Ramdoss et al. 2011b; Higgins and Boone 1996). In addition to communication skills, CBI has been used to teach people with autism social-emotional skills, academics, and daily living skills (Ramdoss et al. 2011a, b, 2012a, b).

Ramdoss et al. (2011a) completed a review on the use of CBI to teach communication skills to people with ASD. Ten studies met predetermined inclusion criteria, and data from 70 participants with ASD were analyzed. The potential of CBI to improve communication has only been evaluated in children 14 years old or younger diagnosed with autism. There were no studies involving adults or individuals with Asperger's syndrome identified in the systematic search procedures. The hardware used in the reviewed studies was commonly available and relatively inexpensive. For example, all of the studies in which hardware components were described utilized machines with 2 GHz of processing speed and 512 MB of RAM or less. Only three of the software programs that were evaluated are available for purchase (Hyperstudio, PowerPoint, and Baldi/Timo) and only Baldi/Timo is specifically designed to provide communication intervention to people with autism. Baldi (later iterations are called Timo) is a program that involves a realistic talking head that produces synthesized speech and has craniofacial movements carefully designed to mimic those observed when a person is speaking in real life. Massaro and Bosseler (2006) used Baldi to teach five children with autism to identify specific pictures based on Baldi's spoken words (i.e., receptive language) and then to produce spoken names for those pictures. An alternating treatment design was used to determine if the image of Baldi's face contributed to the acquisition of the communication skills by comparing a synthetic speech condition without the image of the face and a face plus synthetic speech condition. The researchers concluded that communication skills can be increased within an automated program and that the presence of the life-like face facilitates that process.

The other two programs identified by Ramdoss et al. (2011a) were HyperStudio and PowerPoint. Those programs are designed to deliver multimedia presentations and the specific curriculum or presentation must be created by the practitioner. In those cases, the extent to which the practitioner is able to create a presentation that utilizes reinforcement, prompting, and other research-based instructional strategies would seem more likely to predict outcomes than merely the use of the computer. Further, because the specific presentations used in those studies are not available, replication of those findings is hindered. Ramdoss, Lang et al. concluded that there is insufficient evidence to classify CBI as a research-based approach for communication intervention at this time. However, because all 10 studies demonstrated at least some improvement for all participants, CBI can be considered a promising practice for improving communication.

Assistive Technology for Social Skills

The diagnostic criteria for autistic disorder and Asperger's syndrome both include deficits in social skills (American Psychiatric Association 2000). For example, (a) lack of or inappropriate eye contact, (b) failure to develop peer relationships, (c) lack of joint attention, and (d) qualitative deficits in the extent of social and/or emotional reciprocity (Rao et al. 2008; White et al. 2007). Further, people with ASD may have a different understanding of social relationships and the emotions typically associated with those relationships. A study by Bauminger and Kasari (2000) illustrated the nature of such deficits. These researchers asked 22 children with high-functioning ASD and 19 typically developing children to provide information regarding their friendships, understanding of loneliness, and their own feelings of loneliness. Results suggested that the children with ASD often desired friendship and reported having at least one friend. However, friendships in the ASD group were found to be less developed in terms of companionship and feelings of security. Overall, fewer associations between feeling lonely and having a friend were identified in the ASD group, which could suggest that people with ASD may have a different understanding of the relationship between loneliness and friendship than do people without ASD. These types of social deficits and emotional abnormalities might lead to isolation, bullying, academic and vocational underachievement, and might also exacerbate or cause symptoms of social anxiety that are reported to be prevalent within the ASD population (Attwood 2007; Lang et al. 2010; White et al. 2007).

Given the impact of the social and emotional abnormalities associated with ASD, it is not surprising that assistive technology has been used in an effort to improve social functioning among individuals with ASD. As discussed in the proceeding section, assistive technology to support communication typically involves use of a device that augments and provides alternative forms of communication (e.g., PECS and SGD). Those devices are not typically faded out of communication intervention programs, but remain as a permanent communication modality. Assistive technology used to support social skills, however, is more likely to be instructional and the assistive technology may be faded or eliminated to promote more typical functioning after the target social skill has been acquired. For example, Hopkins et al. (2011) used the computer program *FaceSay* to provide 49 children with autism opportunities to practice attending to eye gaze, discriminating between facial expressions, recognizing faces, and identifying emotions. *FaceSay* involved a series of games in which children practiced each skill by interacting with a realistic human avatar. For example, to teach attending to eye gaze, children were shown two pictures of a human face and asked to determine if the faces were the same or different. Subtle differences in faces could be determined by close examination of the avatars' eye gaze. Similar games taught other fundamental social skills. After the curriculum was completed, participants with more severe autism (relative to the rest of the sample) demonstrated improvement in the ability to distinguish between facial expressions, and participants with high functioning autism demonstrated improvements in identifying facial expressions and corresponding emotions. Both high and low functioning autism groups experienced improvements in social interactions with peers and family members following the intervention.

In some cases, the support provided by assistive technology may be difficult to fade or eliminate. Shabani et al. (2002), for example, used a pager that vibrated using a remote control to prompt three children with autism to initiate a social interaction with other children during play and to respond to the bids for social interaction made by other children. Specifically, when an opportunity to respond or initiate a social interaction was observed, the therapist activated the pager. The child, who had been previously taught to engage in social behavior when the pager was activated, would then initiate a social interaction or respond to a peer's initiation. A reversal design demonstrated that all participants increased the frequency of their verbal initiations and two participants increased their responses to peer initiations. However, when the pager prompts were faded, the performance of two participants' decreased to baseline levels and the third participant's initiations and responses became inconsistent. These results highlight the potential difficulty of fading some assistive technology interventions and suggest the need for continued research aimed at identifying strategies promoting maintenance of acquired skills.

Table 6.2 provides an overview of 11 intervention studies involving assistive technology to improve the social skills of people with ASD. This table was created by searching the electronic databases ERIC and PsychINFO using key terms related to ASD, assistive technology, and social or emotional skills. In order to focus on the most recent research and technology, only studies published during or after the year 2000 were included in the table. Each study is summarized in terms of participant characteristics, assistive technology utilized, dependent variables, and outcomes.

Table 6.2 Summary of intervention studies involving assistive technology that target social or emotional skills in people with autism spectrum disorders

Citation	Participant characteristics	Assistive technology	Dependent variables	Outcomes
Axe and Evans (2012)	Three males with ASD all 5 years old	Video modeling in which an adult model performed eight specific facial expressions (e.g., approval, bored, and calm) and another model reacted appropriately to those expressions	Appropriate responding to facial expressions, for example, saying "I am all done" when the facial expression looks impatient or expressing sympathy "you look bored" when facial expression indicated boredom	Multiple probe across behaviors design demonstrated clear improvement for two participants and following additional instruction variable or inconsistent improvement for the third participant
Beaumont and Sofronoff (2008)	49 (44 males and five females) with Asperger's syndrome between 7 and 11 years old	CBI involving the software "Junior Detective Training" first taught participants to recognize facial expressions, posture, and prosody of avatars and then to interpret the avatar's feelings using those nonverbal cues	Reciprocal social interactions, social responsiveness, initiating and maintaining conversations, interactive play, interpreting facial expressions and posture, and knowledge of anger and anxiety management strategies	Group design with random assignment found that participants in the treatment group had greater improvement in social skills as reported based on parent and teacher reports and were better able to suggest appropriate emotion-management strategies. No significant difference between groups on recognizing nonverbal social cues
Charlop et al. (2010)	Three males with autism 7, 8, and 11 years old	Video modeling that involved the participants watching two models interact during a play setting; models engaged in target social comments, intonation, gestures, and facial expressions	Appropriate social verbalizations, voice intonation, gestures, and facial expressions	A multiple baseline across participants design demonstrated that all three participants made improvements in all four dependent variables and generalized the new skills across settings, stimuli, and people

(continued)

Table 6.2 (continued)

Citation	Participant characteristics	Assistive technology	Dependent variables	Outcomes
Lacava et al. (2007)	Eight (six males and two females) with Asperger's syndrome between 8 and 11 years old	CBI involving the software "Mind Reading: Interactive Guide to Emotions" contains a library of over 400 pictures and movie/audio clips representing different emotions; users interact with the different emotions through quizzes, games, and lessons	Cambridge Mindreading Face-Voice Battery for Children assessed recognition of 15 emotional concepts; The Child Feature-Based Auditory Task assessed recognition of 17 complex emotions using speech segments; Reading the Mind in Films Test-Children's Version assessed ability to emotions in movie clips	A nonequivalent pretest–posttest group design suggested participants improved their ability to recognize basic and complex emotions from face and voice stimuli
Maione and Mirenda (2006)	One male with autism 5 years old and two typically developing peers 5 and 7 years old	Video modeling with feedback; participant with autism watched vignettes of models engaged in a social activity; all three participants were then videotaped during the same activity; the participant with autism then watched the tapes and received feedback	Scripted verbalizations that matched those observed in the videos; Unscripted novel verbalizations; Social Initiations; Utterances were further coded as repeats, unintelligible, and/or adult prompted	A multiple baseline across participants demonstrated that for two of the three targeted social activities video modeling alone was sufficient to increase targeted social skills and following the addition of video feedback social skills increased in the third activity; both scripted and unscripted verbalizations increased but more unscripted verbalizations were observed than scripted

(continued)

Table 6.2 (continued)

Citation	Participant characteristics	Assistive technology	Dependent variables	Outcomes
MacDuff et al. (2007)	Three males with autism between 3 and 5 years old	An audio script was used to prompt bids for joint attention with a potential conversation partner	Verbal bids for joint attention; Scripted bid for joint attention; Unscripted bids for joint attention; Pointing	A multiple-probe across participants design demonstrated that all three participants learned to make bids for joint attention. The skill was maintained and generalized across materials and settings after the script was faded
Sancho et al. (2010)	Two (one male and one female) with autism both 5 years old	Effects of video modeling without supplementary instruction were compared to video modeling with additional practice, prompting, and reinforcement	Scripted verbalizations; unscripted verbalizations; scripted play actions; unscripted play actions	An alternating treatment design demonstrated that both forms of video prompting were found to be effective at increasing social skills but video prompting with supplemental instruction was found to be more effective for one participant
Shabani et al. (2002)	Three males with autism between 6 and 7 years old	A vibrating pager was used to prompt social initiations during play via a therapist with a remote control	Verbal initiations and verbal responses to peers' initiations during a social play activity	An ABAB design demonstrated that all participants increased frequency of verbal initiations and two increased in responses to peer initiations. Prompt fading was only minimally successful with one participant

(continued)

Table 6.2 (continued)

Citation	Participant characteristics	Assistive technology	Dependent variables	Outcomes
Tetreault and Lerman (2010)	Three (two males and one female) with autism 4, 5, and 8 years old	Two participants received point-of-view video modeling plus food reinforcement contingent on watching the video and on performance of target skills during practice. The third participant received video modeling alone	Eye contact plus appropriate social initiation and verbalizations	A multiple baseline across behaviors design demonstrated improvements in the dependent variables for two participants but additional prompting was required to increase targeted social skills in the third participant
Trottier et al. (2011)	Two males 11 years old with autism and six typically developing peers 11 to 12 years old in the same inclusion classroom	Typically developing peers taught the students with ASD to use SGDs during social situations at school	Number of communicative acts by the students with ASD during social situations with peers; Prompts per minute by the researcher to the typically developing peers and by the peers to the students with ASD	A multiple baseline across participants demonstrated that all prompting decreased as the number of communicative acts by the students with ASD increased. Peers can be taught to teach students with ASD to use AT for social interactions
Wichnick et al. (2010)	Three (two males and one female) with autism between 5 and 7 years old	Voice over recording devices with prerecorded audio scripts were presented to participants as they exchanged toys. The scripts and prompts were systematically faded	Response to peer initiation; Scripted response to peer initiation; Unscripted response to peer initiation; Novel (i.e., not scripted or previously heard during intervention) response to peer initiation	A multiple baseline across participants design demonstrated improved responding to peer initiations and the number of novel responses increased as scripts were faded

As suggested by the studies summarized in Table 6.2 and by other recent literature reviews focused on social skills interventions, assistive technology has been successfully used to improve social and emotional functioning of people with ASD (Bellini and Akullian 2007; Rao et al. 2008; Reed et al. 2011; Shukla-Mehta et al. 2010; White et al. 2007). Reed and colleagues conducted a systematic review of 29 intervention studies focused on the use of assistive technology to teach social skills to children with autism. They found that assistive technology had been used to teach children with ASD to: (a) initiate conversations, (b) engage in more sophisticated and social forms of play, (c) utilize social conventions and norms during conversations, (d) respond to the social initiations of others, (e) solve social problems, and (f) identify and regulate emotions and emotional reciprocity. Most of the studies were implemented in applied settings (e.g., schools and homes), utilized sound experimental procedures, included standardized assessments, and resulted in improved social skills. A variety of assistive technology interventions were utilized including CBI (described in the preceding section) and script training (e.g., listening or reading a scripted conversation); however, the most common form of assistive technology used to teach social and emotional skills was video modeling (see Table 6.2). Video modeling and script training are therefore discussed in more detail.

Video Modeling. Typically developing children appear to learn a wide array of skills through observation (Bandura 1977). Video modeling involves watching a video of the target skill being performed and then imitating the modeled behavior or skill (Bellini and Akullian 2007). In addition to social skills, video modeling has been used to teach motor skills, communication skills, self-monitoring, vocational skills, and emotional regulation to people with and without developmental disability (Bellini et al. 2007; Hitchcock et al. 2003). Rayner et al. (2009) identified several variations of video modeling. Specifically, the video may be shot from a first-person point of view (i.e., the observer sees as if through the eyes of the person performing the skill) or from a third-person point of view (i.e., the observer sees a person perform the skill). The person performing the skill is referred to as the model and the model may be a peer, therapist, or the same person with ASD that is receiving the intervention. When the person watching the video is also the model, the intervention may be referred to as video self-modeling (VSM).

VSM is often used when the person occasionally performs the target skill, but the goal of intervention is to increase the rate of occurrence or bring the occurrence of the behavior under the control of some environmental stimulus. If the person with ASD has never engaged in the target skill (precluding it being filmed), a self-modeling video can still be created by editing to remove prompts or to string together several video segments depicting components of the skill, so that the person with ASD can watch himself or herself perform the entire target skill independently even if they have never actually done so in the past (Rayner et al. 2009). For example, Bellini et al. (2007) used VSM to teach two children between the ages of 4 and 5 years old to engage in spontaneous (i.e., unprompted) play behaviors with a peer. First, 1 h and 30 min of video footage of the children with ASD playing with other children was collected. Although a few unprompted social interactions were captured during the play sessions, the raw footage also contained many instances of the children with ASD being prompted by the teachers to interact socially with peers. For example, teachers delivered verbal prompts such as “Ask Emerson to play.” or “Push the wagon so Emerson can ride”. The raw video footage was then edited to remove all evidence of the teacher prompts and to omit any segments containing problem behavior or solitary play. The editing process resulted in three 2 min video segments depicting only appropriate social play behavior without any support or prompting from the teacher. The participants then watched one of the segments every day for 17 school days. After watching each video, the children with ASD were taken to an area with other children and allowed to play freely. Teachers were instructed not to provide any support or prompt to facilitate social interaction during these post intervention free-play sessions, and data on unprompted social interactions between the children were recorded. A multiple baseline across participants design demonstrated an increase in overall social engagement that was maintained even when VSM ceased.

There are several potential advantages to using video modeling to improve the social skills of children with ASD. First, once the video is created, it can be used repeatedly and this repetition and consistency may be particularly conducive to skill acquisition in people with ASD (Ogilvie 2011). Second, video modeling may be a relatively easy intervention for practitioners and typically takes only a few minutes to run the video training session (Shukla-Mehta et al. 2010). Third, in the case of VSM, people with ASD may learn to visualize themselves being successful, which might facilitate the acquisition of other similar skills. In addition to these potential advantages, there is sufficient empirical evidence to support the use of video modeling for teaching individuals with ASD (e.g., Ayers and Langone 2005; Bellini and Akullian 2007; Delano 2007; McCoy and Hermansen 2007; Mechling 2005; Rayner et al. 2009; Shukla-Mehta et al. 2010).

However, previous reviews into the efficacy of video modeling as a technology-assisted teaching procedure for individuals with ASD (e.g., Ayers and Langone 2005; Bellini and Akullian 2007; Delano 2007; McCoy and Hermansen 2007; Mechling 2005; Rayner et al. 2009; Shukla-Mehta et al. 2010) have highlighted several unanswered questions regarding video modeling that should be addressed in future research. Specifically, the majority of studies utilizing video modeling have involved other nonassistive technology components (e.g., direct prompting and reinforcement from a trainer) implemented in tandem with video modeling. In those studies that lack a component analysis, it is difficult to determine if video modeling alone would have been effective. Second, it is not currently known what type of model is most effective for teaching specific skills. For example, is it better to use peer models or self-models to teach social initiations? Finally, the participant characteristics associated with positive outcomes following video modeling need to be delineated to improve the efficiency with which this type of assistive technology is applied. For example, it is not clear if imitation skills represent a prerequisite to successful use of video modeling (Lindsay et al. 2013; Rayner et al. 2009).

Script Training. Script training involves the teacher or therapist planning a specific social interaction in which the spoken lines and/or behavior of one or both people in the social interaction is scripted. After the social interaction is scripted, the participant is either given a written copy of the script or hears it from a recording or a person reading it (Stevenson et al. 2000). The participant is then placed in the social situation referred to in the script. For example, a child with ASD could be given a script on what to say and/or how to act while playing with a peer and then be taken to a play session with a peer. Scripts may also contain prompts for specific behaviors hypothesized to facilitate the social interaction. For example, in addition to scripting speech, a script may also prompt the participant to approach a potential conversation partner, initiate conversation, orientate to the person speaking, make eye contact, wait while the other person talks, and other similar behaviors conducive to the target skill (Wichnick et al. 2010).

The goal of script training is not to produce rote scripted responding, but to offer an opportunity to practice pro-social behaviors. When script training is successful, the individual with ASD does not follow the script verbatim, but is able to deviate from the script in socially appropriate ways and express unscripted ideas (MacDuff et al. 2007). This flexibility and spontaneity during the target social interaction is accomplished by systematically fading the script over time so that the person with ASD can assume ever increasing control over the social interaction as his or her skills improve. Wichnick et al. (2010), for example, used a script-fading procedure to teach three school-aged children with autism to respond to social initiations from their peers while sharing toys. Peers were given toys to share with the participants with ASD. During baseline, the peers gave the toys to the participants and no scripts were provided. During intervention, voice-over-recording devices with pre-recorded scripts were paired with each toy. The peer handed the toy and the device to the participant, and the participant was then prompted to activate the device and repeat the resulting spoken message. Script fading began after at least eight scripted responses were emitted. To fade the scripts, the pre-recorded message was gradually reduced so that it became increasingly less specific. For example, the scripted message "thank you" was faded to "thank…". The message "I like the toy animals" was first faded to "I like the toy…" and then "I like…" and then "I…". The participant was expected to complete the script during the fading process. Eventually, the voice recorder was blank and then not presented at all. A multiple baseline design demonstrated that as the pre-recorded message was faded the number of novel unscripted responses to peer initiations increased. For example, during script fading the following novel utterances were observed "Sharing toys is great," "These (toy) animals are cool," and "We can always play together" even though these utterances had not been scripted during intervention.

As indicated in Table 6.2, script training appears to be most commonly used to increase the duration or quality of social interactions (e.g., longer conversations or extended social play). However, a small number of studies have used script training to increase more basic social skills. For example, MacDuff et al. (2007) used audiotaped scripts to increase the frequency of bids for joint attention by children with autism. The single word “see” was recorded on a device that would play the message when a button was depressed. Pictures of toys were attached to each device, and the corresponding toys were placed in unusual places in the school. Children were taught to orientate to a conversation partner, activate the device, and then point to the misplaced toy (i.e., recruit joint attention). After these skills were acquired, the message was deleted from the device, but the device was still present to facilitate maintenance of the desired response by acting as a mediator (Stokes and Baer 1977). Eventually the devices were removed altogether. The bids for joint attention maintained and generalized to untrained settings and toys. The existing research in support of script training is limited but results like these suggest additional research investigating the potential benefits of script training is warranted.

Assistive Technology for Adaptive and Daily Living Skills

Adaptive and daily-living skills, such as self-care (e.g., grooming, dressing, cooking), organization (e.g., time management, money management), and community or recreational skills (e.g., using public transportation or the library), have been noted as essential for an individual to function successfully and independently (Liss et al. 2001). In addition to increasing independence, acquisition of adaptive and daily living skills might promote self-determination by reducing passivity and learned helplessness (Parmenter 1993). Unfortunately, individuals diagnosed with ASD often struggle to acquire the adaptive and daily living skills necessary to live independently and often come to rely on caregivers for assistance. Smith et al. (2012) investigated the daily living skills of a group of 397 adolescents and adults with ASD over a 10-year period. Latent growth curve modeling indicated that, despite a period of improvement during adolescence and the early 20s, the daily living skills of people with ASD most often plateau short of independent functioning.

A considerable amount of research has been directed toward developing and incorporating a variety of assistive technology solutions for deficits in adaptive and daily living skills experienced by individuals with ASD. Several previous literature reviews have evaluated the intervention research in this area. For instance, Mechling (2008) reviewed studies focused on teaching cooking skills and found that the instructions delivered using picture-based systems, hand-held personal computers, auditory prompting systems, and video models have been effective in enabling people with ASD and intellectual disability to prepare their own meals. Similarly, a review conducted by Morse et al. (1996) revealed that video-taped instructional models and slide show examples can be used to teach grocery shopping skills. Finally, Palmen et al. (2012) noted the practical utility of a variety of high and low technology instructional modalities in teaching domestic skills to individuals with high functioning ASD.

Table 6.3 provides an overview of recent peer-reviewed intervention studies involving assistive technology to improve the daily living skills of people with ASD. This table was created by searching the electronic databases ERIC and PsychINFO using key terms related to ASD, assistive technology, and daily living or adaptive skills. In order to focus on the most recent research and technology, only studies published during or after the year 2000 were included in the table. A total of nine recent studies were identified for inclusion in Table 6.3. Each study is summarized in terms of participant characteristics, assistive technology utilized, dependent variables, and outcomes.

The nine studies summarized in Table 6.3 aimed to teach adaptive and daily living skills to a total of 20 participants. Nineteen of the participants had a diagnosis of autism and one study involved a participant with a diagnosis of PDD-NOS (Mechling and O'Brien 2010). Eighteen of the participants were male. Participant ages ranged from 3 to 36 years. All participants in the studies summarized in Table 6.3 acquired the targeted adaptive and daily living skills that were supported or taught using assistive technology. The same basic approach and general instructional strategy was used across studies. Specifically, to determine pre-intervention skill levels, participants were first provided an opportunity to engage in the target skills in the natural environment and then some form of assistive technology was used to teach the target skill. Instructional procedures included prompting, prompt fading, and reinforcement. In order to promote generalization, study authors incorporated images and videos taken directly from the natural environment in order to make the instructional environment and materials more closely resemble the natural environment (Stokes and Baer 1977). Following intervention, performance was assessed again in the natural environment. In seven of the nine included studies (Ayres et al. 2009; Mechling and O'Brien 2010; Rosenberg et al. 2010; Shipley-Benamou et al. 2002; Sigafoos et al. 2005; Sigafoos et al. 2007a, b, c; van Laarhoven et al. 2010), follow-up probes to assess the maintenance of acquired skills were also conducted and, in the majority of cases, the skill was maintained.

In these studies, a variety of dependent variables with respect to adaptive and daily living skills were targeted. Five studies examined the utility of assistive technology for teaching some aspects of food preparation (Ayres et al. 2009; Bereznak et al., 2012; Shipley-Benamou et al. 2002; Sigafoos et al. 2005; van Laarhoven et al. 2010). For instance, van Laarhoven et al. (2010) used in vivo picture prompts and video prompts to teach a 22-step microwave pasta preparation skill to two adolescents with autism. Four studies examined the effectiveness of assistive technology on teaching some aspects of housekeeping skills (Bereznak et al. 2012; Shipley-Benamou et al. 2002; Sigafoos et al. 2007a, b, c; van Laarhoven et al. 2010). For example, Sigafoos and colleagues examined the efficacy of computer delivered video prompting on teaching dish washing skills to three adults with autism. Two studies focused on using CBI to teach skills that are essential for independent living such as using public transportation (Mechling and O'Brien 2010) and purchasing groceries (Hutcherson et al. 2004). Rosenberg et al. (2010) compared commercially available videotapes and customized videotapes to

Table 6.3 Summary of intervention studies involving assistive technology that target adaptive and daily-living skills in people with autism spectrum disorders

Citation	Participant characteristics	Assistive technology	Dependent variables	Outcomes
Ayres et al. (2009)	Two males and one female with autism between 7 and 9 years old	CBI delivered step-by-step instruction using "I Can" software to teach preparing food and setting table	Percentage of steps done correctly on the computer and in vivo for making a sandwich, setting table, and making soup	A multiple baseline across target skills demonstrated that all three participants mastered the skills and generalized to a natural environment
Bereznak et al. (2012)	Three males with autism between 15 and 18 years old	Video modeling delivered via iPhone for making copies, preparing noodles, and using washing machine. Students used the iPhone as a self-prompt in the natural environment	Percentage of correct responses for each step of the task analysis for each skill	A multiple probe across behaviors design replicated across participants demonstrated all three participants increased ability in all three target skills
Hutcherson et al. (2004)	One male with autism16 years old (three other participants without ASD)	Multimedia CBI program "Project SHOP" displayed photographs of items in a grocery store; participants matched items in progressively more difficult and life-like computer simulated activities	Percentage of correct responses and time required to locate grocery items	A multiple probe across behaviors design demonstrated that correct responses in the community store increased and anecdotal reports suggest time to locate items decreased
Mechling and O'Brien (2010)	One male with ASD 20 years old (two other participants without ASD)	Video recordings with voice over and still photographs were presented on a laptop computer; video models were shot from first-person perspective	Using the request to stop the bus signal at the correct place	A multiple probe design across participants demonstrated that students were able to stop and exit the bus at the correct place without additional in vivo training
Rosenberg et al. (2010)	Three males with autism between 3 and 5 years old	Commercially available video modeling program and a customized video modeling program involving familiar people	Number of correctly completed hand washing steps from a task analysis	A multiple baseline across participants design demonstrated that the commercially available video resulted in some skill acquisition and the customized video further increased skill acquisition

(continued)

Table 6.3 (continued)

Citation	Participant characteristics	Assistive technology	Dependent variables	Outcomes
Shipley-Benamou et al. (2002)	Two males and one female with autism between 5 and 6 years old	First-person point of view video modeling for each task	Percentage of steps done correctly for the tasks: making orange juice, preparing and mailing a letter, caring for pets, and table setting	A multiple probe design across tasks and replicated across participants demonstrated all three participants acquired all three skills and maintained at 1 month follow up
Sigafoos et al. (2005)	One male with autism 36 years old (two other participants without ASD)	First-person point of view video modeling	Percentage of task analysis steps done correctly to prepare popcorn using a microwave oven	A delayed multiple probe design across participants demonstrated that two of the three participants (including the one with autism) acquired the skill and maintained it at 10 week follow up
Sigafoos et al. (2007a, b, c)	Three males with autism between 27 and 33 years old	A video modeling and fading procedure that first involved video segments of individual steps in the task analysis and then combining those steps together for a complete video as means to fade AT support after skill acquisition was demonstrated	Percentage of dish washing steps done correctly based on a task analysis	A multiple baseline across participants design demonstrated all 3 participants acquired the skill. However, when the video modeling was ceased performance deteriorated. Performance improved following the combined video segment fading procedure
Van Laarhoven et al. (2010)	Two males with autism 13 and 14 years old	Compared picture and video prompts. Each participant was taught one skill with picture prompts and one skill with video prompts	Percentage of clothes folding and pasta making steps done correctly based on a task analysis and number of prompts required	An alternating treatment design for each participant demonstrated that video prompting was associated with more independent correct responses and fewer prompts

examine effectiveness for teaching hand washing skills to three children diagnosed with autism.

Across the studies, a variety of assistive technology systems were used to deliver instruction. Three studies evaluated CBI to promote independent and daily living skills in individuals with ASD (Ayres et al. 2009; Hutcherson 2004; Mechling and O'Brien 2010). For instance, Ayres et al. (2009) delivered instructions using a computer software program to teach food preparation and table setting to three children (ages 7 to 9 years old) with autism. Instruction was provided by the software program *I Can—Daily Living and Community Skills*. This instructional program is designed to present a video simulation of the environment for three unique tasks (i.e., setting table, making soup, and making sandwich) and required children to respond by arranging materials in a simulated environment (e.g., putting utensils on the table). Initially, participants were assessed in vivo on their ability to complete the selected tasks in the absence of intervention. CBI was then provided and participants reached the mastery criteria for each task. Following CBI, in vivo performance was evaluated again and data indicated the skills had been acquired.

Three studies used portable laptop computers (Sigafoos et al. 2005, 2007a, b, c; van Laarhoven et al. 2010), two studies used a television and video player (Rosenberg et al. 2010; Shipley-Benamou et al. 2002), and one study used an iPhone (Bereznak et al. 2012) to deliver video prompts. For instance, Sigafoos and colleagues evaluated the effects of computer-delivered video prompting procedures to teach three adults with developmental disabilities (including one participant with autism) to make microwave popcorn. Video prompting involved showing a video clip of one step of the making popcorn task analysis at a time. Following the video prompt, participants were given the opportunity to initiate and complete the step. After this, a video clip of the next step in the task was presented and so forth until the completion of the task. The skills necessary to make microwave popcorn were acquired and maintained even after video prompting was withdrawn at the 10-week follow-up.

Clinical Application

The studies reviewed in this chapter described the use of assistive technology for enabling and enhancing the communication, social, and daily living/adaptive behavior skills of individuals with ASD. With respect to the first category of communication studies, our summary of 10 major literature reviews revealed that assistive technology has been successfully used to develop a range of communication skills, including requesting preferred objects and activities, rejecting non-preferred objects and activities, naming/labeling objects/pictures, and initiating conversational exchanges. However, it would appear that most of the research has to date focused on teaching what might be viewed as relatively beginning communication skills for basic self-regulation functions (e.g., requesting preferred objects). Given the potential for assistive technology to enable much more sophisticated and complex communication interactions, there would seem to be some value in extending the existing literature to explore the use of these types of assistive communication technologies for enabling participants with ASD to enter into more complex and prolonged communicative exchanges.

The studies reviewed in this first category revealed that three major types of assistive technology have been successfully used to enhance the communication skills of individuals with ASD. These include lower-tech (picture-exchange) systems and higher-tech systems. Among the higher tech-systems, researchers have employed a variety of SGDs as well as various applications of CBI. Given the overall positive findings from these reviews (see Table 6.1), we can conclude that PECS, SGDs, and CBI all appear to represent viable and generally effective tools for enhancing communication functioning of individuals with ASD. Given that the most severe communication deficits are associated with the more severe forms of ASD (i.e., Autistic Disorder, rather than Asperger's syndrome or PDD-NOS), it would seem that there will likely be greater future interest in using assistive communication technologies in the education and treatment of individuals with more severe symptoms of ASD. However, the review of studies into using assistive communication technologies in the education and treatment of individuals with communication disorders (Chap. 4), suggests that such technologies might be effectively applied to enhancing more advanced communication (e.g., literacy, cell phone, and internet/social media usage). These latter skills would seem potentially useful educational objectives for individuals functioning at higher adaptive levels within the autism spectrum.

Most of the studies into the use of assistive communication technologies for individuals with ASD were conducted in home, school, or clinical settings and with communicative partners who were familiar with the child and with the nature of the assistive technology. This raises the important clinical issue as to the effectiveness of PECS, SGD-, and CBI-based communication in community settings with unfamiliar listeners. In an important early study, Rotholz et al. (1989) demonstrated that a low-tech picture-based communication system was more effective for community-based communication than the use of manual signs. This finding was most likely related to the fact that the community-based listeners were not sign literate, but they were able to interpret the persons' picture-based communications. In a later study, Durand (1999) found that unfamiliar listeners responded appropriately (without training) to the SGD-based communication initiations of five students with developmental disabilities. While these findings suggest that both low- and high-tech assistive communication technologies may be effective in community setting with unfamiliar listeners, there are relatively few studies into this important clinical issue, especially regarding the use of CBI and the newer generation of iPad-based SGDs. Additionally, more information is needed regarding community members' perceptions of different types of assistive technology.

With respect to the second category of studies targeting social and emotional skills, our summary of 11 intervention studies revealed that assistive technology has been successfully used to develop a range of social/emotional skills, including responding to facial expressions, identifying emotional states (e.g., anger, anxiety), using social gestures, initiating social interactions, and recruiting attention/interaction. This range covers a number of the areas that have been described as causing problems for people with ASD, but the literature is somewhat limited in that other important areas have not yet been covered (e.g., empathy). Given the potential for assistive technology to assist individuals with ASD in these areas of social difficulty, there would seem to be some value in extending the existing literature to explore the use of these types of assistive communication technologies for enabling participants with ASD to acquire other social skills and learn to identify and appropriately express a wider range of emotions.

The literature in the social/emotional area is also limited with respect to the range of assistive technology employed. Most studies have used CBI or video modeling. There would seem to be scope for investigating other (portable) technologies for addressing the needs in the social/emotional areas, such as perhaps iPhones, virtual reality, and robotics. Still, the results of these 11 studies were sufficiently impressive to make the case for using assistive technology within a more general systematic instructional approach for teaching new social/emotional skills to persons with ASD.

With respect to the third and final category of studies targeting daily living and other adaptive skills, our summary of nine intervention studies suggested again that assistive technology can successfully used to develop a range of daily living/adaptive behavior skills, including preparing meals/snacks, using office and household appliances, locating grocery store items, signaling a bus to stop, washing hands, mailing a letter, caring from pets, setting the table, washing dishes, and folding laundry. This range covers a number of the functional skills that would certainly seem to be common. The diversity of skills suggests that assistive technology may have relatively broad applicability in the daily living/adaptive skills domain. The literature in the daily living/adaptive behavior skills area is, however, somewhat limited with respect to the range of assistive technology employed. As was the situation in the social skills domain, most studies in the daily living/adaptive skills domain have used CBI or video modeling (e.g., Jowlett 2012; Moore et al. 2013; Shrestha et al. 2013). While effective, there would seem to be considerable potential perhaps for evaluating newer emerging assistive technology to assist persons with ASD in the performance of daily living/adaptive behavior skills.

Whether the aim is to use assistive technology to improve communication, social/emotional, and/or daily living/adaptive behavior, an important clinical issue relates to determining when assistive technology is required and then selecting the most effective and efficient form of assistive technology. Careful consideration of these two issues would seem paramount to success and to ensuring a good fit between the person's needs and the technology. Along these lines, Sigafoos and Iacono (1993) highlighted a number of variables that should be assessed and considered in selecting assistive communication technology for individuals with developmental disabilities. These variables included: (a) degree of motor control,

(b) levels of alertness, (c) impulsiveness, (d) motivational factors, (e) the person's existing skills, and (f) the demands of the environments in which the assistive technology will be required. Consideration of such factors may assist not only in selecting the assistive technology technology, but also in designing the intervention that is almost always necessary to teach individuals with ASD to use the assistive technology.

Consistent with the suggestions of Sigafoos and Iacono (1993), Smith et al. (2005) suggested that decisions regarding assistive technology should be made by a team of people with relevant expertise and/or that know the individual with ASD well (e.g., parents, teachers, and behavior analysts). In the decision-making process, the team should consider the: (a) characteristics of the individual who will use the assistive technology (e.g., existing skills, educational goals, and preferences), (b)the environments where the skill enabled by assistive technology will be expected to occur, and (c) the social validity of the assistive technology (Smith et al. 2005).

When considering the individual characteristics of the person with ASD during the assistive technology selection process one additional factor that should be considered is the person's preferences for specific types of assistive technology. van der Meer et al. (2011) conducted a review of studies that assessed a person's preference for using different AAC options. A total of seven studies involving 12 participants were reviewed. Across studies participants were taught to use SGD, picture exchange, or sign language. After having been exposed to each option, structured opportunities for each participant to select between the different AAC options were created in order to determine an individual's preference. The AAC option selected the most often was then considered to be the option preferred by the participant. In most cases, the participants did indicate a preference for one option over another; specifically, 67 % of participants preferred the SGD and the remaining 33 % preferred picture exchange. The reviewers recommend that preference assessments should be part of the process when selecting an AAC modality because incorporating such an assessment enables individuals with disabilities to exert some modicum of self-determination.

In addition to considering the preferences of the intended users of the assistive technology, the preferences of their family and other caregivers (e.g., friends and teachers) should also be considered. Some forms of assistive technology may be impractical, inappropriate or even impossible in some family contexts (e.g., Jurgens 2012). For example, expensive assistive technology solutions that involve computers and similar handheld electronics (iPads) may be too expensive for a family with low income. While other families may have the economic resources, they may lack the technical proficiency to use new age technology. For example, to use the iPad as a SGD a family must purchase the device and the software application, a combined total of approximately $700 US. Additionally, they must be able to install the software, find the application on the device, set up the application to perform in the desired way, and be able to trouble shoot when the device malfunctions. Such financial and technical requirements may render otherwise effective assistive technology impractical for many families. Finally, families may prefer one form of assistive technology over another because of alignment with family norms and routines. For example, some families may commonly use handheld electronics and using an iPad as a SGD would not disrupt the typical expectations and routines. While other families may prefer their child not spend so much time looking at a screen and may prefer PECS. When selecting assistive technology, the family should be shown the options and their preferences should be considered in tandem with the other considerations.

Conclusion

The overall conclusion arising from this overview of studies is that assistive technology is a useful tool as part of a larger intervention approach for addressing some of the communication, social/emotional, and daily living/adaptive deficits associated with ASD. The studies reviewed here provide important illustrative examples of how a range of assistive technologies have been successfully used to address a number of specific skills across these three broad functioning domains. Such illustrations may be helpful to clinicians who are interested in making use of assistive technology, provided of course the use of assistive technology is also acceptable to stakeholders (e.g., families). Consideration of a number of personal attributes and stakeholder preferences are likely to enhance the overall experience of using such technologies with persons with ASD and may also help to prevent premature/inappropriate abandonment of such technology. The mere provision of assistive technology is not sufficient to ensure that effective and functional use of the assistive technology will follow. Instead, the evidence to date suggests that individuals with ASD will often require explicit, deliberate, systematic, and often intensive instruction to learn how to use the prescribed assistive technology. Research extending the use of these types of assistive technology for more complex skills in community settings is needed to further gauge the more general usefulness of assistive technology in the education and treatment of persons with ASD.

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Chapter 7
Assistive Technology for People with Behavior Problems

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Introduction

Problem behavior is a broad construct that continues to spur attention and debate within many disciplines such as clinical psychology, special education, and psychiatry (Emerson and Einfeld 2011). Different terminology is sometimes used in lieu to describe problem behavior and include such terms as challenging behavior, destructive behavior, and so on. While there may be subtle nuances affiliated with different terminology these terms are generally addressing the same set of behaviors. Problem behavior is sometimes described as the symptomatic expression of emotional or interpersonal maladjustment in children (enuresis,

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encopresis, withdrawal, self-harm, hostility; American Psychiatric Association 2000). Problem behavior may also be prevalent with various disability types such as autism spectrum disorder (ASD), intellectual disability, attention deficit hyperactivity disorder (ADHD; Vaughn et al. 2011). For example, those diagnosed with ASD engage in restrictive, repetitive, and stereotyped patterns of behavior (these patterns are part of the diagnostic criteria). Ostensibly such rigid patterns of behavior will be problematic in at least some contexts for all persons with ASD.

While a plethora of terms and possible etiologies of problem behavior abound we believe that it is still possible to arrive at a robust definition of problem behavior that distills such variety. Problem behavior encompasses two fundamental properties: behavior that is (a) harmful to the person's health and safety or to the health and safety of others sharing the person's environment and/or can (b) interfere with the person's access to age-appropriate regular community settings. This definition is purposefully broad. It can therefore accommodate an infinite number of types or topographies of behavior regardless of etiology. This definition also allows for contextual sensitivity when defining problem behavior. For example, masturbation is problematic in a public setting such as a grocery store, but may be acceptable in the privacy of one's bedroom.

Problem behavior is typically described across four broad categories including aggression, self-injury, stereotyped behavior, and property destruction (Emerson and Einfeld 2011; Sigafoos et al. 2003). Then again some disciplines such as child psychiatry may describe problem behaviors developmentally (problems occurring predominantly in childhood or adolescence; Gillberg et al. 2006). Aggression is a deliberate act of violence or threat of such against another. Self-injury involves behaviors that produce harm to self. Self-injury can be dramatic and dangerous such as banging one's head against an object or it may seem innocuous at first glance but produce deleterious outcomes in the long term (e.g., hand mouthing). Stereotyped behaviors involve nonfunctional repetitive behaviors (pacing, hand weaving) that are not harmful. However, such stereotyped behaviors may interfere with adaptive programming and may be stigmatizing in community settings. Property destruction involves breaking and damaging materials in the immediate environment. While there are a variety of different topographies of problem behavior reported under each of these categories, some frequently reported categories are reported in Table 7.1.

Table 7.1 Frequently reported topographies of problem behavior

Aggression/Other	Self-Injury/Bio-behavioral	Stereotyped Behavior[1]	Property Destruction
Hit with hand	Head hit open hand	Hand flapping	Break windows
Hit w' object	Head hit fist	Body rocking	Tear materials
Kick	Eye poke	Finger flicking	Break chairs
Scratch	Head hit object	Object manipulation[6]	Rip clothes
Bite	Pinch/scratch	Head weaving	Breaks electronics
Pull hair	Pica[2]	Pacing	
Pinch	Bruxism[3]		
Verbal abuse	Hand mouthing		
Fire starting	Self-cutting		
Elopement	Enuresis[4]		
Off-task	Encopresis[5]		

[1] These patterns of stereotyped responding do not typically produce injury to self
[2] Eating inedible objects
[3] Teeth grinding
[4] Urinary incontinence
[5] Fecal incontinence
[6] Using everyday toys/utensils in a repetitive nonfunctional manner

Diagnostic Characteristics of Populations Using Assistive Technology to Treat Problem Behavior

This section of the chapter provides an overview of the diagnostic characteristics of individuals who have received assistive technology to treat problem behavior. When reviewing the empirical intervention literature regarding assistive technology and problem behavior, we noted that a particular constellation of diagnoses was recurring. A lot of the research focused on the use of assistive technology with school children diagnosed with *Emotional and Behavioral Disorders* (EBD) or (ADHD). We also noted that a substantial body of the intervention research focused on individuals with (ASD) and *Intellectual/Multiple Disabilities* (ID). Interventions with these latter groups (ASD and ID) tended to occur in multiple settings (e.g., adult day care) in addition to school settings and incorporated a broader age range of individuals than interventions with the EBD and ADHD individuals. An overview of these diagnoses and the problem behaviors associated with such conditions will give the reader a deeper understanding of the assistive technology interventions in the next and penultimate section of this chapter.

Emotional and Behavioral Disorders

According to the Surgeon General of the United States, approximately 20 % of children suffer from a mental health disorder at some point in time (Department of Health and Human Services, 1999). The terms themselves, “emotional” and "behavioral" disorders tend to be used interchangeably. In essence the term EBD describes a group of children who suffer from mental health issues that are serious enough to interfere with the child's social, emotional, and academic functioning. EBD is not a formal psychiatric diagnosis but rather a classification system used by Federal agencies. For example, the US Department of Education (2004) describe "emotionally disturbed" as a student, who is unable to learn (excluding intellectual, sensory, or health causes), does not maintain satisfactory interpersonal relationships, exhibits inappropriate behavior or feelings under normal circumstances, may appear unhappy and develop anxiety or fears associated with personal or school problems (Vaughn et al. 2011). Such students are eligible for special education services or reasonable accommodation to the regular education curriculum.

Students diagnosed with EBD experiencing difficulties achieving at school tend to engage in behavioral problems (e.g., truancy, aggression, property destruction), and can experience social isolation. It is often recommended as part of a comprehensive support package for such children that a functional behavioral assessment be conducted to identify maintaining contingencies for such problem behavior and that these results be translated into a behavioral improvement plan. Behavioral improvement plans will include such strategies as creating an emotionally supportive environment (positive listening and responding, use of humor), establishing clear rules or contingencies (e.g., token economies), conflict resolution training (instruction on sharing, compromising, apologizing, etc.), and promoting self-control.

Developing self-control is often described as a critical element of behavioral improvement plans for students with EBD (Menzies et al. 2009). Students are taught to gain self-control over their behavior and emotions. This is achieved through a set of strategies used to teach students to identify their own problem behavior, monitor that behavior, and self-reinforce appropriate behavior. Likewise students are taught to use similar strategies to monitor their academic and social behavior. Self-control strategies have been shown to increase on-task behavior (Rock 2005), improve academic performance (Levendoski and Cartledge 2000), and decrease aggressive behavior (Gumpel and Shlomit 2000) with this population. It is within the context of these self-control interventions that assistive technology has been empirically evaluated to increase adaptive and decrease problem behavior for students with EBD. It is to this research that we will turn our attention in our review of assistive technology and problem behavior.

Attention Deficit Hyperactivity Disorder

ADHD is a formal psychiatric diagnosis (American Psychiatric Association 2000). Prevalence statistics for this disorder vary but in general these statistics describe a disorder that is on the rise in our society. Approximately 9.5 % of children 4–17 years of age were diagnosed with ADHD as of 2007 (Centers for Disease Control and Prevention 2013a). Boys (13.5 %) are more likely to be diagnosed with ADHD than girls (5.6 %; Centers for Disease Control and Prevention 2013a). Children with ADHD are eligible for special education services under the Individuals with Disabilities Education Act (IDEA, US Department of Education 2004) or instructional accommodation within regular education services under the Rehabilitation Act of 1973 (Section 504; US Department of Health and Human Services 1973).

There are several subtypes of this disorder (e.g., inattentive type, hyperactive impulsive) but we will merely give a cursory overview of the key symptomatology to orientate the reader as they review assistive technology interventions with these children in the next sections of the chapter. Generally, these children are characterized by three constellations of symptoms—inattention, hyperactivity, and impulsivity. *Inattention* is often manifested in such difficulties as failing to pay attention to details, unable to maintain attention to tasks, failing to listen to instructions, not completing tasks, poor organization, losing materials, resisting tasks that require sustained attention, easily distracted, forgetful. Some of the symptoms of *hyperactivity* include fidgeting and squirming, difficulty staying in seat during classroom activity, talking too much, difficulty playing quietly, excessive running and climbing. *Impulsivity* is often evidenced by such behaviors as blurting out answers in class, interrupting other students as they answer questions, butting into play activities, and difficulty with turn taking.

In terms of treatment, there are a variety of educational strategies that can be used to enhance academic success with this population. Additionally, medication can successfully control such symptoms. Stimulant medication such as Ritalin (methylphenidate) can reduce symptoms with clinical significance in about 70 % of children treated (Barkley 2008). Educational interventions can also reduce the impact of these symptoms, often in combination with medication. For example, visual displays can be used to enhance attention to task. Checklists can be used to reduce distractibility during work. Color-coded work sheets can focus attention to pertinent detail. Flash cards can be used to enhance memory and attention. As the reader can see, a variety of simple assistive technologies can be used to focus or enhance the learning experience with children diagnosed with ADHD.

Autism Spectrum Disorders

ASDs are a group of developmental disabilities that are characterized by deficits in communication and social skills and by restrictive and repetitive patterns of behavior (American Psychiatric Association 2000). The latest prevalence figures indicate that approximately 1 in 88 children suffer from this disorder (Centers for Disease Control and Prevention 2013b). Chapter 6 provided the reader with a detailed overview of the use of assistive technologies with this population. However, a large number of the studies reviewed for this chapter included persons with ASDs. So some overview of the condition is warranted to position our review of assistive technology to treat problem behavior with this population. It is common that children diagnosed with ASD are reported to engage in such problem behavior as self-injury, aggression, property destruction, and stereotypies (Matson and Nebel-Schwalm 2007). As many as 64–94 % of samples of children with ASDs have been reported to engage in challenging behavior in recent studies (Murphy et al. 2009; Jang et al. 2011). There is also a high correspondence between the diagnosis of ASD and intellectual disability (Matson and Shoemaker 2009).

Several of the characteristics of ASD predispose these children to problem behavior. All of these children experience *deficits in communication skills* and approximately 50 % of these children never develop speech (National Research Council 2001). Early deficits in communication skills are associated with the presence of problem behavior (Sigafoos et al. 2006). In fact, much of problem behavior can be understood as a form of communication designed to access desired items/activities and avoid or escape aversive situations (Sigafoos et al. 2003). As much as 60 % of cases of self-injury in individuals with severe disabilities (not just limited to the ASD diagnosis) have been shown to serve access or escape/avoidance functions (Kahng et al. 2002). Likewise *social skills deficits or excesses* may also present as problem behavior—with individuals being unable to initiate, maintain, or terminate social interactions in an appropriate fashion. *Stereotypes or restrictive/repetitive behavior* may take the form of simple physical movements such as body rocking, hand flapping, to organizing items in nonfunctional patterns. It can also take more sophisticated forms such as obsession with certain activities (e.g., train or bus schedules) or topics (e.g., dinosaurs). These repetitive/restrictive patterns of behavior can present as behavior problems in and of themselves as children will engage in these patterns to the detriment of other activities. In fact restrictive/repetitive behaviors tend to become particularly problematic when the child enters school and is now required to focus their energies on other new learning activities. These individuals can also engage in additional problems behaviors such as aggression and self-injury when they are redirected from restrictive/repetitive behaviors to engage in other activities. Presumably these secondary problem behaviors occur in order to escape alternative activities that interfere with the restrictive/repetitive repertoires.

Assistive technologies can be used in multiple ways to mitigate the effects of problem behavior with these individuals. For example, a variety of technologies can be used as communication devices or strategies to support individuals with limited communication. If challenging behavior is motivated by communication needs then children may be taught to use assistive technologies to communicate these desires in a socially appropriate fashion. These communication strategies should eventually replace the problem behavior. Such instructional design to teach alternative appropriate communication using assistive devices is termed functional communication training (Durand 1999). Another usage of assistive technologies might be to present instruction in a manner that enhances attention to task. For example, academic instruction might be delivered via computer or device (e.g., iPad). Engaging with computers and such can be a highly motivating experience for these children and as such may enhance academic or on-task behavior and mitigate problem associated with task avoidance.

Intellectual and Developmental Disabilities

IDD incorporates a heterogeneous group of individuals who have mental and/or physical disabilities that impair language, learning, mobility, and daily functioning. The term *intellectual disability* has relatively recently replaced the term *mental retardation* to describe individuals with limited cognitive functioning who also experience challenges with age-appropriate living skills (Luckasson et al. 2002). The term *developmental disability* is a broad descriptor that incorporates persons with ID and individuals who have sensory, motor, and multiple disabilities that have occurred prior to adulthood. IDD therefore incorporates a wide spectrum of abilities—from individuals with milder levels of ID to individuals with severe/profound ID and multiple physical disabilities. Approximately 1 % of the school population is diagnosed with IDD (Vaughn et al. 2011). Approximately 15 % of this population exhibits problem behavior that warrants some form of clinical attention (Sigafoos et al. 2003).

In general terms, this population exhibits deficits across a wide variety of cognitive and adaptive skills. Many may experience deficits with communication skills that may predispose them to engage in problem behavior. This is a similar issue as described with persons with ASD. Others may engage in problem behavior that serves a self-stimulatory/stereotyped function. This is often seen in persons with severe/profound disabilities who may have additional sensory deficits (e.g., visual and or hearing impairments). The more severe the IDD, the greater the probability of problem behavior (Sigafoos et al. 2003). In a relatively recent analysis of a sample of individuals with profound IDD a total of 82 % engaged in self-injury and stereotypy while 45 % engaged in aggressive behavior (Poppes et al. 2010).

Assistive technology has been used in a number of ways to help reduce problem behaviors with this population. Similar to the ASD group, this technology can be as augmentative and alternative communication modes for those who use problem behavior to access or escape from items, settings, activities, etc. In other words, assistive technology can be used as part of a broad-based communication strategy to enhance appropriate communication skills and thereby replace problem behavior that had previously been used as a means of communication. Assistive technology can also be used to provide stimulation or access to stimulation (via microswitches) in order to reduce stereotyped forms of problem behavior particularly in persons with profound multiple IDD. Finally, assistive technology can be used to deliver consequences/feedback to reduce the probability of problem behavior in some individuals with IDD.

Overview of Assistive Technology Research to Manage Problem Behavior

In this section, we provide a selective review of published empirical interventions that have used assistive technology to manage problem behaviors for the populations described in the previous section of this chapter. The section is organized by technology strategies and not disability categories. In many of the studies described in this section the authors do not specifically measure problem behavior as a primary dependent measure. Often the focus is on increasing adaptive behaviors that are incompatible with problem behavior (e.g., increasing on-task behavior to replace off-task behavior). This reflects the educational agenda (rather than focusing on decreasing problem behavior) of many of these authors. It may be helpful for the reader to refer back to the disability categories (and problem behaviors associated with these categories) as they review the empirical studies in this section. Assistive technology interventions are divided into two broad categories—antecedent cue/self-monitoring strategies and consequence-based strategies.

Antecedent Cue/Self-Monitoring Strategies

Antecedent cue/self-monitoring strategies encompass a collection of empirical studies that focus on enhancing stimulus control of adaptive behavior and/or teaching persons to monitor their own behavior. Assistive technologies used to promote antecedent cue/self-monitoring that have ranged from simple technology (e.g., paper/pencil/timer) to more sophisticated technology such as iPods or microswitch technology. Types of assistive technologies evaluated in empirical peer-reviewed studies and described under antecedent cue/self-monitoring strategies include paper/pencil/timers, computers, iProducts, and microswitches.

Paper/Pencil/Timer

In this section, we overview a total of four studies that have used combinations of relatively simple technologies to increase academic and social behaviors (thus decreasing incompatible problem behavior) with students with a variety of disabilities (Graham-Day et al. 2010; Legge et al. 2010; Rafferty 2012; Rafferty and Riamondi 2009).

Legge et al. (2010) examined the effects of a MotivAider® on the on-task behaviors of three boys (ages 11–13 years) with ASD. The boys attended a special education classroom and were integrated into regular classrooms during certain periods of the school day. The MotivAider® is an electronic pager that can be clipped to the pants or belt and can produce vibration on a fixed or intermittent time schedule. The MotivAider® also has a digital display that can show the countdown in seconds or through graphic display. This device can be used to prompt persons to record previous activities or current behavior. The distinct advantage of this device lies in its unobtrusiveness. Other devices that have been used in a similar fashion have produced an auditory prompt (e.g., sports wristwatch, kitchen timer etc.). Auditory prompts can be distracting and stigmatizing in classroom situations as such devices may draw negative attention from peers.

The three students were taught to use the MotivAider® to self-record on-task behavior during independent seatwork in mathematics class. Independent seatwork sessions were 20 min. Students were given a set of math exercises to complete during these independent seatwork sessions. There were approximately six other students in the classroom during these sessions. Students were taught to use the MotivAider® prior to intervention. During intervention the MotivAider® vibrated every 2 min. When the device vibrated the students were to record a plus (+) or a minus (−) beside each of three items on a self-recording form, "eyes on work," "in my seat," and "doing work." If the students recorded a plus for all three behaviors they were scored as being on-task for that 2-min interval. The teacher also collected data on the accuracy of self-recording for the three students. The MotivAider® prompt was then faded from a 2-min interval to a variable time interval schedule for all three students. Finally, maintenance probes under original baseline conditions (self-recording form and MotivAider® absent) were conducted for 3 weeks. The results of this study demonstrated increase in on-task behavior during independent seatwork sessions when the MotivAider® plus self-recording was in place. On-task behavior was a little more variable (similar to baseline performance) during the maintenance conditions. These results indicate that self-monitoring of on-task behavior using the MotivAider® as and assistive technology device was effective in increasing adaptive responding. The converse of these findings is also true—this assistive technology-based intervention reduced off-task behavior for three students with ASD during independent seatwork in class.

Graham-Day et al. (2010) implemented a self-recording protocol to increase on-task behavior with three 10th graders (all were 16 years of age) who were diagnosed with ADHD. The intervention was implemented in study hall. Study hall consisted of 13 students with various special needs. The intervention was implemented across all 13 students but data were collected on the three target students only. All three students were reported to exhibit high rates of off-task behavior and low rates of homework completion. On-task behavior was targeted as the primary dependent measure for the study and was defined by such behaviors as sitting in desk, facing forward, feet on floor, eyes directed toward academic tasks, and asking academic related questions. Self-monitoring sessions lasted 20 min. During sessions students used a checklist to record whether they were on-task (circle "yes") or off-task (circle "no"). Students were prompted to self-record by an audiotape that emitted a chime on a variable time schedule of 2 min. This gave the students 15 opportunities to record during a 20-min session. Accuracy of recording was also assessed and students were reinforced (piece of candy) if their on-task recording concurred with the recordings of an observer. Academic grades were also assessed at the beginning, middle, and end of the study. Finally, student and teacher satisfaction with the self-monitoring intervention were evaluated.

The results of the intervention indicated that the students could accurately self-record and that there were significant increases in on-task behavior for all three students. As the intervention was implemented across the entire study hall the potential stigmatizing effects of using an audible chime to prompt self-monitoring were mitigated. Both the students and teachers were generally positive about the intervention. Interestingly, academic grades did not increase, but in fact decreased over the intervention period. Academic grades may be too distal, a measure over the short period of the intervention. Perhaps, if the intervention was extended over an entire semester or academic year positive change might occur on this measure. Overall, the results are promising and demonstrate that simple assistive technology (audiotape with self-recording sheet) could increase on-task behavior during study hall for students with ADHD.

Rafferty and Raimondi (2009) examined the comparative effectiveness of self-monitoring of attention (on-task) versus self-monitoring of performance on three students (age range 8–9 years old) with a diagnosis of EBD. All three students had a history of inappropriate behavior (inattentiveness, disruption, noncompliance) and were below grade level in mathematics. The study took place in self-contained classrooms in a public elementary school. Interventions were conducted during regular 15-min math practice sessions following lunch each day.

In the self-monitoring of attention condition the students were prompted via an audiotape (a tone was emitted) at 5-min intervals giving the students three opportunities to self-record each session. At the tone the students were to ask themselves, "At this moment am I doing my work?" The student was to record "yes" or "no" on their self-monitoring card. Finally, the student completed a daily graph that indicated the number of "yes" (on-task) responses for that day. This graph presented daily feedback for the entire intervention period and was kept in the student's work folder. In the self-monitoring of performance the students were asked to self-monitor at the end of the work period (15 min) and not during the session. The work tasks were identical across both self-monitoring interventions. At the end of a work session, the student accessed an answer key and tabulated the number of problems answered correctly for that session. Then the student graphed the number of correct answers completed on the graph for that session. This graph presented the number of correct answers per session during this condition and was also kept in the student's work folder. Overall, the results indicated that self-monitoring of performance resulted in greater productivity and accuracy. The students also rated self-monitoring of performance more favorably than self-monitoring of attention (on-task).

In a final example, Rafferty (2012) examined the effects of self-monitoring coupled with the MotivAider® with four students (ages 7–8 years) with a diagnosis of EBD. The intervention was conducted during a summer intensive reading program. The intervention was conducted during whole group (a total of 15 students in class) and small group instruction. Small group instruction size varied from 1:1 to 3:1 for each student. All four students were described as *at risk* or of being *at some risk* with regard to early literacy skills. The teacher described the students as posing behavior problems during instruction (not following directives, going to the bathroom during instructional time, looking out the window) and this resulted in them routinely not completing assignments.

Similar to the Legge et al. (2010) study, students in this study were to use the device as a prompt to self-monitor on-task behavior. The MotivAider® was unobtrusively attached to the students' pants or belt. The prompt was a gentle vibration that occurred every 2 min, at which point the students were to record whether they were on-task or not (similar self-recording procedures as in Rafferty and Raimondi (2009) described earlier in this section). On-task behavior increased over baseline levels for all four students with the implementation of the MotivAider® plus self-monitoring protocol. On-task behavior of the four students reached similar levels to that of other students in class—verifying the social validity of the intervention. Additionally, the students made meaningful advances in their oral reading fluency with the implementation of the intervention. Once again, the findings of this study support the veracity of relatively simple assistive technology coupled with self-management protocol to increase appropriate academic behavior (being on-task during instruction). On-task behavior is an incompatible repertoire of behavior to such behaviors as out of seat, self-stimulation, distracting other students that are frequently observed with students with such diagnoses as EDB, ADHD, and ASD.

Computers

In this section, we overview a total of three studies that have used various types of computers as a form of assistive technology used in antecedent cue/self-management interventions to reduce problem behavior with students with a variety of disabilities (Blood et al. 2011; Gulchak 2008; Soares et al. 2009). The technology in this section might be described as being somewhat more sophisticated than the previous section.

Gulchak (2008) taught a student with EBD to use a handheld computer to self-monitor behavior. This was the first known published study to go beyond paper and pencil to help students to record their own performance. The student involved in this study was an 8-year-old male who was diagnosed in the clinically significant range for internalizing and externalizing behaviors. He attended a self-contained classroom with nine other students of similar diagnoses. The research targeted on-task behavior that was defined as keeping hands away from face, completing work assignment, raising hands to ask questions. The intervention was implemented during a 1h reading period 4 days per week. The entire class was involved in these reading exercises that included direct instruction or independent reading, comprehension exercises, and activity review. The structure of this reading period remained constant throughout the study with no changes in difficulty of the tasks.

A "Palm Zire 72" handheld computer was used. This device is larger than a deck of playing cards and about half the thickness. It has a touch screen that the user manipulates using a stylus. The software program used to self-monitor on-task behavior was called "HanDBase." One page of the device displayed the on-task behaviors while the other page allowed the student to check whether he was on-task or not by checking a box "yes" or "no" on the screen using the stylus. The device was placed in the student's desk and produced an alert (chime) every 10 min at which point the student was to take the device from his desk, review the on-task behavior list, and then record whether they were on-task or not for that period. The results of this study suggest that the student could accurately use the handheld computer to self-monitor on-task behavior. There was also moderate evidence that the intervention produced increases in his on-task behavior during reading periods in school.

Soares et al. (2009) implemented a self-monitoring intervention to reduce self-injury and tantrums and increases task completion for a 13-year-old boy who was diagnosed with Asperger syndrome. The intervention was conducted in a resource classroom during reading activities. The reading activity consisted of daily 45-min sessions in which the student was to independently read passages and answer questions related to the text. Task difficulty remained constant throughout the intervention. The student had three opportunities to self-monitor during the reading period. Once he completed a task he showed it to his teacher. The teacher verified that the task was completed. At this point, the student was given access to a recording sheet on a desktop computer. He cut and pasted a "Mickey Mouse" image into the appropriate section of a self-monitoring sheet on the screen. He had the opportunity to cut and paste Mickey three times on his self-monitoring sheet during a reading period. The daily checklist was then printed and given to the student as a permanent product each day. The "Mickey Mouse" image was used as the student obsessed on this character. In fact, he had a large doll of this character in his self-contained classroom and he engaged in problem behavior any time when he was separated from the toy. In effect, this self-monitoring intervention used an item of obsession as a reinforcer (cut and paste "Mickey Mouse") to increase task completion and reduce problem behavior. Overall, the self-monitoring intervention reduced problem behavior and increased task completion for this student.

In a final example of this section, Blood et al. (2011) used an iPod Touch to reduce off-task and disruptive behavior for a 10-year-old boy with a diagnosis of ADHD and EBD. The boy was receiving modifications to the general education curriculum in science, social studies, music, and physical education. He received math instruction during part of the school day in a special education classroom. Math instruction was highly structured and delivered by a paraprofessional at a classroom table with 2–3 other students. He engaged in frequent disruptive behavior during instruction including talk without permission, blurting out, singing, and use of inappropriate language. In addition to disruption, on-task behavior was also measured and included following directions, attending to the teacher, appropriately manipulating class materials. Prior to the intervention, he was placed on a token system to reduce problem behavior and this token system remained in place during the iPod Touch intervention. The intervention was conducted during math sessions with each session lasting approximately 20–25 min. Instructional tasks during math sessions were similar throughout the study.

The intervention consisted of two phases—video modeling and video modeling plus self-monitoring. In the video modeling phase the student observed a video on an iPod Touch approximately 5 min before math class. The video lasted approximately 4 min and consisted of two same-aged peers engaging in on-task behavior during math instruction. The video also included a narration that described appropriate behaviors (e.g., "Keep your eyes on the white board when the teacher is showing you something. Answer questions from the teacher in a normal quiet voice. You should be watching and listening quietly."). In the second phase of the study the student was taught to self-monitor. First, video was captured of the student being on-task and off-task during math class. This video was downloaded on the iPod Touch and the student was systematically taught to accurately differentiate when he was on-task and off-task using a pencil and self-recording sheet. Once he could accurately self-record on- and off-task behavior the video modeling plus self-recording phase of the intervention was implemented. In this second phase the student again observed the video model on the iPod Touch immediately before match class. During math class the student used the paper and pencil self-monitoring protocol. He was prompted at 2-min intervals (beep from the iPod Touch) to record his behavior during class.

An 8 GB iPod Touch was used to store the video model and to deliver the prompts during self-monitoring. The video model was created using a Cannon ZR500 video camcorder and this material was then edited and converted to video footage compatible with the iPod Touch. This video modeling plus self-monitoring intervention produced decreases in disruptive behavior with concomitant increases in on-task behavior for the student.

Microswitches

The use of microswitch technology as an antecedent cue/self-monitoring strategy has been predominantly used to reduce stereotyped behavior in individuals with profound/multiple disabilities (see Lancioni et al. 2009 for a comprehensive review). A variety of microswitch technologies have been included in programs to treat stereotyped problem behavior such as tilt, pressure, and optic microswitches. These microswitches have often been adapted to capture minimal levels of motor behavior with the participants in these studies (e.g., foot, back, tongue, head responses). There are two general types of intervention strategies that use such microswitches as antecedent/cue self-monitoring protocol: (1) microswitches that produce positive stimulation when an adaptive alternative behavior to stereotypy occurs, and (2) microswitch clusters where an adaptive response (monitored by one microswitch) produces positive stimulation only when the stereotyped response (monitored by the second microswitch) does not occur. Examples from each of these two types of microswitch intervention are described below.

An example of a type 1 intervention is illustrated in Lancioni et al. (2011). In this study, the authors examined the use of microswitch technology to treat drooling, a prevalent difficulty with individuals with severe intellectual and physical disabilities. One of the participants in this study was Graham, a 46-year-old man with severe to profound intellectual disability. He possessed residual vision due to optic atrophy and suffered from severe (partially controlled) epilepsy. He had some echolalic speech and could perform some simple occupational tasks such as collecting and matching objects. He attended day care rehabilitation where he received physiotherapy and was engaged in simple leisure activities. Drooling was reported to be always present. Graham seemed to overproduce saliva and rarely swallowed or tried to clean his mouth spontaneously.

The assistive technology consisted of a special napkin placed around his neck. The lower half of the napkin was thick and absorbent and could be replaced when wet. Graham was to use this thicker section of the napkin to wipe his mouth. Two pressure sensors were embedded in the thick section of the napkin. A mouth wiping response (bringing the lower part of the napkin to the mouth and pushing the napkin to the mouth) would activate at least one of these pressure sensors. The activation of a pressure sensor in the napkin triggered a microprocessor that in turn activated an MP3 player. The microprocessor and MP3 device were small items that were housed in the upper part of the napkin. Thus, when Graham wiped his mouth he received 10 s of highly preferred music and songs. This music and songs were systematically identified using a preference assessment prior to the study. Once the 10 s of music elapsed, Graham could again wipe his mouth and activate the music once more. Eventually, additional music was added to the MP3 device (approximately 10 s of additional but less preferred music) to increase the intervals between mouth wipes with Graham (a lower frequency of mouth wiping looked more socially acceptable but continued to be effective in terms of eliminating drooling). Chin wetness and mouth wiping were measured when the technology was present and absent.

Results of the research demonstrated that assistive technology resulted in substantial increases in mouth wiping and virtually eliminated chin wetness. The technology continued to be effective for controlling drooling at a 3-month follow-up. This research demonstrates that simple assistive technology (pressure microswitch, microprocessor, MP3 device) can be used to deliver positive stimulation that established a routine behavior pattern (mouth wiping) to control the effects of drooling for an individual with profound multiple disabilities.

Several examples of the second type of microswitch intervention strategy (use of multiple microswitches) will be presented. These combined microswitch technologies serve a dual purpose of increasing adaptive responding while simultaneously managing/reducing stereotyped responding.

Our first example of using multiple microswitches to treat problem behavior can be found in Lancioni et al. (2007b). As mentioned above, microswitch clusters usually involve one microswitch that is used to access positive stimulation when problem behavior (monitored by a second microswitch) does not occur. This combination of microswitches is valuable as it allows for the learning of adaptive responding while simultaneously controlling or reducing problem behavior (Lancioni et al. 2009). Lancioni et al. (2007b) used a microswitch cluster to treat hand mouthing and eye poking for a 12-year-old boy. The boy was in the profound range of intellectual disability. He suffered from congenital cerebropathy with spastic tetraparesis, possessed minimal residual vision, and suffered from seizures. He had no speech, consistent communication, or self-help skills, and was confined to a wheelchair. The authors report that hand mouthing (bringing the fingers or other parts of the hand into or over the mouth) and eye poking (placing the fingers into or over the eye) occurred independent of social contingencies. Both eye poking and hand mouthing were monitored by optical microswitches (photocells) that were held to the right side of the boy's face via light wires and these wires were in turn attached to a headband (worn during sessions). The boy's left arm did not function—hence the reason for the positioning of the photocells at the right side of the head. The adaptive response consisted of repeated lifting and shaking of the right foot (while seated in a wheelchair) and this activated a motion microswitch attached to the foot. The adaptive response produced 8 s of pleasant stimulation (determined via a prior preference assessment) and consisted of music, recorded voices of favorite persons, light displays, and vibratory stimulation. Microswitch responses were inputted to a control system and this system recorded all three responses including adaptive responding in the absence of problem behavior. Eventually, the boy could access pleasant stimulation via the foot response but only when problem behavior did not occur. For example, if the boy attempted to eye poke or hand mouth while pleasant stimulation was occurring then this was recorded by the optic microswitch(s) at the head and pleasant stimulation was immediately interrupted. In other words, the boy could only access pleasant stimulation when he did not engage in hand mouthing and eye poking. The results of the study demonstrate substantial decreases in problem behavior with concomitant increases in foot responses. This intervention model is posited by the authors as a form of self-determination whereby the boy learned to control his problem behavior in order to access alternative pleasurable consequences via the adaptive response.

In a second example of multiple microswitches Lancioni et al. (2010) implemented a microswitch intervention to reduce dystonic stretching of one or both arms either forward or sideward for Glen, a 5 year–old boy with a diagnosis of severe to profound intellectual disability. He was diagnosed with encephalopathy that was due to premature birth and perinatal hypoxia and he also presented with spastic tetraparesis combined with dystonic movements. He spent most of his day in a wheelchair. He possessed no speech or means of communication and his vision was severely impaired (he was reported to see relatively large objects within 1 m and at the center of the visual field). Glen lived at home with his parents and attended a day activity center that focused on physiotherapy and general stimulation goals.

Dystonic stretching is a relatively prevalent behavior pattern in individuals with multiple disabilities and can interfere with ongoing habilitation efforts. However, until this study no research had attempted to reduce this problem behavior with this population. In essence, such patterns of behavior were seen as an essential characteristic of the disability and not as behaviors that were amenable to change.

The intervention consisted of Glen manipulating five to seven objects that were placed in an open box in front of him (base of box 37 × 27 cm and 10 cm high). The items placed in the box included such preferred items as favorite toys. These items were loosely tied to the bottom of the box. Adaptive responding for Glen consisted of manipulating these objects (by placing both hands in the box). This response was deemed adaptive as it was incompatible with dystonic arm stretching. In terms of microswitches, there were a number of microswitches placed in the box (including optic and tilt microswitches) that were placed under and on the objects. Manipulation of the objects activated the microswitches and produced preferred stimulation (these preferred stimuli were identified prior to the intervention using a stimulus preference screening approach). Preferred stimulation included music, familiar voices, vibratory input, and light displays for about 8 s contingent manipulation of any of the items in the box. The second component of the microswitch cluster consisted of magnetic watch-like sensors attached to both wrists. These sensors detected the removal of one or both arms from the box (any distance greater than 10 cm for 2 s or more). Arm removal from the box produced termination of the preferred stimulation. Arm removal rather than dystonic arm movements was targeted for intervention as it was considered a precursor to dystonic arm movements. The effectiveness of this intervention was evaluated using an ABAB design. In the A phase manipulation of the objects in the box did not activate microswitches to produce positive stimulation nor did removal of arms from the box produce termination of stimulation. In the B phase microswitches produced the consequences described above. High levels of object manipulation (and therefore low levels of dystonic arm stretching) occurred in the B phases of the research. These findings indicate that this microswitch cluster was effective in controlling dystonic arm stretching for Glen.

A final example of a microswitch cluster was developed by Lancioni et al. (2008) to manage head control in persons with multiple disabilities. Poor head control (e.g., head forward tilting) can be considered a problem behavior as it interferes with educational programming and can have deleterious consequences on physical condition (such as breathing, muscle tone etc.). As head tilting occurs almost continuously and in the absence of social contingencies for those affected it would appear that such behavior is stereotyped in nature (i.e., not maintained by social consequences).

In a series of case studies, Lancioni and colleagues have demonstrated that appropriate head control can be accomplished during active engagement sessions using microswitch cluster technology (e.g., Lancioni et al. 2004, 2005, 2008). Lancioni et al. (2008) present the case example of Sid, a 7-year-old boy with encephalopathy, spastic tetraparesis, and severe to profound intellectual disability. He was confined to a wheelchair and had little hand, arm, and leg movement coupled with minimal trunk control. His head tended to tilt forward constantly. He had typical hearing but suffered from minimal residual vision. Sid lived at home with his parents and attended a day facility that focused on physiotherapy and stimulation. The adaptive response selected for Sid was foot lifting and a tilt microswitch was attached to his leg in order to capture this response. A tilt microswitch was also attached to Sid's head via a headband. The head microswitch was activated when the head was upright and deactivated when his head was tilted. Sid was first taught to use the foot lifting response to access preferred stimuli such as music, noises, chimes, television clips, and a variety of vibratory inputs. These preferred stimuli had been identified for Sid via a preference assessment screening procedure prior to the study. Activating the foot microswitch produced 8 s of a selection of these preferred stimuli. Once Sid had consolidated the foot lifting response to access preferred stimuli he was then required to hold his head upright (monitored by the second tilt microswitch) while making the foot lifting response in order to access preferred stimulation. If his head tilted then preferred stimulation did not occur or was immediately terminated. Results of this study show that Sid was able to learn to access the preferred stimuli via the foot-lifting response while keeping his head in an upright position.

Consequence-Based Strategies

This second major section encompasses peer-reviewed studies that have used assistive technology as part of a consequence-based strategy to reduce problem behavior. Assistive technology has been used in two general ways as part of consequence-based interventions. First, assistive technology has been used to automatically deliver consequences contingent upon problem behavior that subsequently reduces problem behavior. Second, assistive technology has been used as part of augmentative communication interventions to enhance overall communication skills. Sometimes these augmentative communication interventions are designed to teach the person to access positive consequences (e.g., social interactions with individuals, access to desired tangible items) or escape/avoid aversive consequences (e.g., difficult tasks). As with the antecedent cue/self-monitoring strategies described earlier, this section summarizes consequence-based strategies according to categories of technology utilized including picture exchange communication system (PECS), speech generating devices (SGD), and microswitches.

Picture Exchange Communication System (PECS)

From a technology standpoint, PECS is a relatively simple picture card system designed to teach communication skills to persons with severe communication deficits. What is sophisticated about PECS is that it incorporates a curriculum and instructional methodology to establish and expand a communication repertoire using this picture card system. Persons are taught a communication-based system using black and white or color two-dimensional drawings. These drawings (about 2.5 X 2.5 cm each) are usually attached via Velcro™ to a notebook or binder. The person is taught to arrange these drawings to create various sentences. Teaching the person to use PECS involves a six-step process which includes handing drawings to a communication partner, selecting among drawings and handing to a communicative partner, discriminating among drawings, creating sentences using drawings to request items, answering questions, and commenting on objects/activities.

Increasing numbers of peer-reviewed empirical interventions are documenting the effectiveness of PECS to increase communication skills in persons with a variety of communication impairments (Lancioni et al. 2007a). Naturally, the primary dependent measures included in these studies focus on communication skills (e.g., acquisition of PECS skills, changes in initiations, requests, speech, etc.). A number of studies involving PECS have also measured concomitant changes in problem behavior with the implementation of the PECS system. Problem behavior is associated with communication deficits (Sigafoos et al. 2003) so it makes sense to assume that overall increases in communication skills might have a positive impact on problem behavior. Two of these studies that have examined this possible relationship are described below.

Charlop-Christy et al. (2002) taught two young children (3 and 5 years of age) with a diagnosis of autism to use the PECS system. Both children possessed no spontaneous speech and engaged in prelinguistic communication patterns (e.g., pointing to or leading adults to desired objects/activities). Problem behaviors included elopement, grabbing items from other children, kicking, screaming, and banging objects. While the communicative function of these problem behaviors were not assessed the authors hypothesized that they served to access desirable items or escape from academic tasks. Each week during PECS training the children were assessed under an academic and play context. Primary measures included spontaneous communication but problem behavior was also measured in both contexts. Again, problem behavior was not directly addressed as part of the intervention but was systematically measured prior to, during, and following PECS training. The results demonstrate a gradual decline in problem behavior during PECS training with a virtual elimination of such behavior following training. These findings add substance to the dictum that increasing communication in general will have a positive effect in terms of reducing problem behavior.

In another study, Conklin and Mayer (2011) evaluated the use of PECS with adults with severe disabilities. PECS training was implemented in a fashion similar to that described above. One of the participants, a 51-year-old female with a diagnosis of severe intellectual disability and cerebral palsy engaged in problem behavior. She could not talk and used a few simple signs (point to mouth when hungry and to stomach when she needed to use the restroom). Her problem behavior included grunting and screaming that escalated to bouncing up and down in her wheelchair. A functional assessment process involving interviews with staff and observational data were gathered prior to the PECS training to identify the maintaining contingencies of problem behavior. The results of the functional assessment indicated that her problem behavior was maintained by access to preferred tangibles and activities. Problem behavior was systematically assessed prior to intervention, during PECS training, and at 6 months following PECS training. The results of Conklin and Mayer (2011) replicated those of Charlop-Christy et al. (2002) in that there was a reduction in problem behavior with PECS training that continues once training ends.

Speech Generating Devices (SGDs)

SGDs or voice output communication aids and SGD software such as talking word processors are relatively recent assistive technologies and can be quite effective in terms of empowering individuals with significant communication impairments (Mirenda and Iacono 2009). A number of studies have used SGDs as part of an intervention to replace problem behavior with appropriate communication skills. These studies all adhere to a particular format that includes, assessing the function of challenging behavior (attention, escape, access to tangible items), selecting an SGD based on participant characteristics, incorporating the results of the functional assessment as part of the intervention. Three such studies are outlined below.

Durand (1993) described an intervention with Joshua, a 3-year-old boy with severe intellectual disability. Joshua lived at home with his parents and attended a public preschool. He had no formal communication system and was reported as having a language age of 15 months. He was capable of feeding himself and was cooperative with self-help skills routines. No physical disabilities were described. His parents were interviewed regarding problem behavior and reported that it occurred primarily around meal and snack time. Parents also noted that he was very fond of food. Joshua's problem behavior consisted of tantrums and included crying, screaming, and hitting others. His parents described his problem behavior as being frequent. A teacher and assistant teacher were administered the Motivation Assessment Scale (Durand and Crimmins 1992) and the results of this functional assessment indicated that Joshua's behavior was tangibly maintained (access to food).

Intervention was targeted at those times when behavior was problematic (mealtimes) and the communication response selected to replace the problem behavior was "I want more." A Wolf ™ communication device was used with Joshua. The author notes that this device was selected based on cost and durability considerations (it can withstand some physical abuse). The Wolf ™ uses synthesized speech and is activated using a pressure pad. Joshua was then taught to use the communication device to signal that he wanted more food during mealtimes. Parents and teachers used a combination of instructional prompts such as physically guiding Joshua's hand to press the device during meals. All activations of the device were reinforced with food while problem behavior was ignored during training. Training continued for 2 weeks until Joshua used the device on five consecutive occasions without any instructional prompts. Joshua continued to independently use the device to request food following training while his problem behavior remained at very low levels. An interesting addition to this study is that the author measured expressions of affect during intervention. Affect included measures of positive facial expression and smiling. Joshua's positive affect increased dramatically during mealtimes with the introduction of the augmentative communication system. This additional measurement of affect adds further to the veracity of using augmentative communication devices to replace challenging behavior with this population.

Durand (1999) reported an intervention with Ron, a 9-year-old boy diagnosed with autism and severe intellectual disability (reported language and mental age of 45 and 38 months, respectively). He was reported to use some words but these were not used in a contextually appropriate manner. He did not speak when prompted. His problem behavior was aggression and was defined as hitting forcefully with his hands. Ron was described as being very aggressive and targeted family, teachers, and fellow students. Assessment and intervention were carried out in Ron's classroom with subsequent generalization probes conducted in the community by his teachers. His teacher and teacher aide completed the Motivation Assessment Scale and then an analog functional analysis was conducted. The results of both the rating scale and analog functional analysis indicated that Ron's aggression was maintained by access to attention from others. Following these assessments the author met with parents, teacher, and an assistive technology professional to agree upon an augmentative communication device that would be appropriate for Ron. The Introtalker™ was selected as it requires little force to press the keypad, it is a relatively robust device, and it uses digitized speech that is highly intelligible to the listener. The Introtalker™ was programmed with one phrase to request attention, "Would you help me with this?" Ron was then taught to use his device to request attention in the classroom. Instruction continued for approximately 4 weeks. Throughout the school day Ron was prompted (physical, gestural, and verbal prompts) to use his device to gain attention. Prompts were gradually faded (teaching staff waited between 3 and 5 s before delivering a prompt) to promote independence. Instruction continued until Ron used his device independently in the appropriate context on five consecutive occasions. This training in the classroom lasted approximately 4 weeks.

Ron's aggression was virtually eliminated in the classroom with the introduction of the communication device. Corresponding with the decrease of aggression there was a concomitant increase in spontaneous communication for Ron. A very interesting extension of this work was that generalization of the intervention to a regular community setting was assessed. Ron enjoyed visiting a local magazine store. Prior to the intervention his aggression attempts were measured in the store. The teacher was present to block any attempts at aggression toward customers and staff. Aggression was quite high in the store prior to the intervention. Ron was again escorted to the store once he had reached independent performance with his communication device in the classroom. Ron independently used his device to request attention and aggression was reduced dramatically in the magazine store. Additionally, store staff responded to 100 % of his requests for help/attention. In sum, Ron learned to use his communication device independently in the classroom and he spontaneously generalized the use of this device to a community setting. Problem behavior was virtually eliminated in both contexts.

In a final example of an SGD intervention, Olive et al. (2008) taught a 4-year-old girl with severe autism to use such a device to increase communication and decrease problem behavior. The child attended preschool in the mornings and spent the afternoons at home with her mother. The functional assessments and intervention were conducted in the home. The mother acted as therapist. Prior to intervention a series of functional assessments were conducted with the mother including an interview and functional analysis. The results of the interview and functional analysis indicated that problem behavior (elopement, screaming, hitting, biting) occurred to access attention from the mother. Problem behavior was particularly problematic when the mother's attention was diverted to other tasks such as household chores. The child was taught to use a Four Button Touch Talk Direct™ device. Each of the buttons had a prerecorded message (in the child's own voice) requesting that the mother engage in an activity with her. The activities included reading together, art activities, and games. As the mother engaged in household activities she frequently returned to the child (who was sitting at the kitchen table) and prompted her (physical and verbal prompt sequence) to activate the SGD at which point the mother would engage the child in the selected activity. The intervention produced decreases in problem behavior and increases in requesting using the SGD. Post-treatment interview indicated that the mother was very happy with the results of the intervention.

Microswitches

In this section, we describe two studies that have used microswitches as part of an intervention to reduce problem behavior. The first study described in this section utilized microswitch technology to automatically produce a consequence contingent upon problem behavior to reduce challenging behavior (Lancioni et al. 2005). Lancioni et al. (2005) is by no means the only peer-reviewed research describing technology that is used in this fashion (automatic production of consequences contingent upon problem behavior). However, the Lancioni et al. (2005) study is significant in that it uses very gentle consequences contingent upon problem behavior making the use of such technology acceptable as a treatment/support approach for persons with severe/multiple disabilities. The second study described in this section incorporates the use of a microswitch to operate an audiotape that served as a form of augmentative communication (Steege et al. 1990).

Lancioni et al. (2005) evaluated the use of a microswitch to deliver prompts to reduce persistent tongue protrusion. The participant involved was a 39-year-old woman who was reported to be functioning in the severe to profound range of intellectual disability. She attended a day activity center where she engaged in simple activities such as sorting and listening to music. She possessed no intelligible speech but could understand simple directions such as to withdraw her tongue. The behavior targeted for intervention was tongue protrusion and was defined as the tongue sticking out of the lower lip. Observations prior to intervention or when the intervention was withdrawn demonstrated that she engaged in tongue protrusion at or above 50 % of the time. Tongue protrusion also seemed to occur independent of the social context. Assistive technology consisted of (a) an optic sensor (miniphotocell) attached to the lower lip using medical tape, (b) a signal transmission box, and (c) a walkman. Both the Walkman and signal transmission box were placed in a pocket of the woman's clothing. The optic sensor was activated when tongue protrusion occurred and this activated the Walkman that delivered a phrase to prompt the woman to withdraw her tongue. Tongue protrusion was virtually eliminated with use of this technology. However, each time the technology was withdrawn protrusion returned to prior levels (approximately 50 % of the time). The authors note that while the optic sensor location might be too intrusive for use over extended periods of time it might be valuable to consider fading the technology perhaps to phrases intermittently delivered by the Walkman alone. This technology therefore served to automatically prompt the woman to withdraw her tongue each time protrusion occurred. It proved to be highly effective and virtually eliminated self-stimulatory behavior for sessions of anywhere between 20 and 60 min.

Steege et al. (1990) reported an intervention with Dennis, a 6-year-old boy who was nonverbal, nonambulatory (confined to a wheelchair), and was diagnosed with profound intellectual disabilities. He possessed no independent communication skills and was dependent on others for all self-care needs. He was referred to a hospital inpatient unit because of problem behavior and intervention took place in a classroom that was located in this inpatient unit. Dennis engaged in self-injury consisting of hand, wrist, and arm biting. This self-injury, while present since Dennis was 2 years old, had recently increased in severity and frequency, causing open wounds on his hands and arms. Interviews with Dennis's mother and teacher indicated that self-injury was most problematic when he was engaged in self-care routines (e.g., face washing, hair combing, tooth brushing). These self-care tasks were subsequently included in the demand conditions of an analog functional analysis. Results of the analog functional analysis indicated that self-injury occurred almost exclusively during the demand condition for Dennis. The results of the analog functional analysis therefore indicated that Dennis engaged in self-injury primarily to escape self-care tasks. The augmentative communication device used in this study included a contact (pressure) microswitch (15×15 cm) which when pressed operated a tape recorder which played the message "Stop!". The intervention consisted of teaching Dennis to press the switch during grooming routines producing a removal of the task for 10 s. He was physically guided to press the switch by the therapist or he could independently press the switch. In either case the pressing of the switch produced removal of the task for 10 s. If

Dennis engaged in self-injury during instruction the task was continued (he was not allowed to self-injure and was physically guided through the task). This intervention produced a rapid decrease in self-injury with a concomitant increase of prompted and independent use of the augmentative communication device. Dennis was further evaluated at 6 months following the intervention and these follow-up results remained positive with high levels of independent use of the communication device and low levels of self-injury.

Clinical and Academic Implications

This chapter presents a brief overview of the nature of problem behavior and the support of individuals with such behavior using assistive technologies. We did not limit our overview to any one clinical population, but examined the use of assistive technologies across a broad spectrum of disabilities (ADHD, EDB, ASD, ID). The review was also not limited by other characteristics such as age of participants, settings in which the intervention occurred and so on. We did limit our review to intervention studies that used an empirical design and were published in peer-reviewed journals. Our review of these empirical articles was selective or illustrative in nature. We certainly did not conduct an exhaustive review of all the empirical articles published on the use of assistive technology to treat problem behavior with diverse populations. Nonetheless, we will attempt to distill the clinical and/or academic implications of the work reviewed in the remainder of this section.

A number of general points can be made regarding the use of assistive technology to control problem behavior. First, despite the broad array of assistive technologies used and the diverse populations, age groups, and contexts overviewed in this chapter, it appears that interventions involving assistive technology can be quite effective in reducing or eliminating problem behavior. Interventions involving assistive technology successfully reduced behaviors that ranged from off-task during math or reading instruction to dangerous forms of self-injury such as head hitting. Assistive technologies were successfully introduced into a wide array of contexts including classrooms, adult day centers, and community settings such as grocery stores. Age (3–51 years) and disability range (EBD to severe/profound multiple disability) also attest to the utility of assistive technologies as part of an intervention strategy.

Second, the vast majority of studies reviewed did not focus the intervention on the reduction of problem behavior per se. Rather studies focused on increasing adaptive and incompatible responses to the problem behavior. For example, self-monitoring strategies including timers and self-recording sheets were used to prompt school children to remain focused on the task at hand (e.g., math exercises). On-task behavior is an adaptive response that is incompatible with reported problem behaviors such as out of seat and talking to fellow students. SGDs were used to increase appropriate requests for attention, tangible items, and breaks from activities. Such communicative responses replaced problem behaviors such as aggression and self-injury. Assistive technologies can therefore be used as part of an intervention strategy that is designed to increase adaptive incompatible repertoires to replace problem behavior.

Third, assistive technologies in the majority of these studies were part of a comprehensive and relatively (instructionally) complicated intervention plan. For example, with antecedent intervention strategies students were always taught to discriminate when they were engaged in appropriate versus problem behavior and to accurately record this information. This involved the use of instructional strategies such as modeling, role-play, instructional prompts, data collection, corrective and positive feedback on the part of the trainers to achieve such skills in the students. Likewise, complicated microswitch technology with individuals with multiple disabilities involved systematically identifying preferred consequences and delivering instruction on the appropriate use of microswitches. Using SGDs to replace problem behavior as part of a functional communication intervention involves the systematic analysis of consequences maintaining problem behavior and then explicitly training the person to use the SGD to access the outcomes that were previously accessed via problem behavior. In other words, assistive technology is no panacea to treat problem behavior. Rather, assistive technology is a component of fairly sophisticated intervention strategies. So the proper use of assistive technology to support persons with problem behavior will require clinicians who are highly trained in the use of positive applied behavioral interventions including the use of assistive technologies.

Fourth, in many of the studies described in this chapter, the technologies used are not "out of the box" devices, but were tailored to the needs of the person. In addition, the context in which the intervention is to be conducted plays a critical role in device selection. For example, many of the simple self-recording strategies for self-monitoring were developed by the trainers for the specific children and problem behaviors that were addressed in the studies. Many of the microswitches described in the work of Lancioni and colleagues are unique and ingeniously developed to capture very minimal yet consistent patterns of behavior with individuals who are physically challenged.

Context also plays a critical role in device selection. For example, several studies used the MotivAider® to prompt self-recording for students. The MotivAider® delivers a gentle vibration when worn unobtrusively on the pants. Alternative prompting devices such as timers that deliver auditory feedback may tend to stigmatize the student. Durand (1999) chose to use an Introtalker™ that uses digitized speech to deliver a request/comment. He did not use a communication strategy such as PECS. One of the key goals of Durnad (1999) was to promote generalization of the new communication skills into community settings. The use of the Introtalker™ would promote such generalization as it produces speech that can be understood by novice listeners. Generalization of communication skills to novice listeners in the community would not have been as effective had PECS been used. It would be difficult for novice listeners to understand the meaning of the two-dimensional PECS drawings which would result in communication breakdown and the probable reemergence of problem behavior.

Fifth, persons other than the researchers are ultimately required to implement and monitor the use of these assistive technology interventions. This includes classroom teachers, frontline staff, and parents. As mentioned above, these assistive technology interventions are quite sophisticated in terms of instructional design and data collection requirements. Those who will ultimately implement these interventions should therefore be trained to do so. Training can include lectures/descriptions on the values and uses of assistive technology. Supervised practice with feedback on instruction and technology use should also occur. Finally, in vivo monitoring and feedback of parents and staff as they implement such strategies should also occur.

Sixth, a common theme throughout all the studies reviewed was that some form of assessment of the participant was conduced prior to the intervention. Additionally, ongoing assessment of the intervention occurred during the implementation phase. At a very minimum, pre-intervention assessments included an overview of the diagnostic characteristics of the participant coupled with informal interviews of the teachers regarding the problem behaviors exhibited in criterion environments (e.g., acting out during math class). In other studies, very detailed pre-assessments were conducted such as multiple forms of functional assessment to identify maintaining contingencies for problem behavior. Pre-assessment of the person is necessary to tailor the intervention. There is no one to correct answer as to what such pre-assessment protocol should look like. However, some form of functional assessment might be prudent to isolate or at least rule out possible social factors that might be maintaining problem behavior. Ongoing assessment of changes in adaptive and/or problem behavior was also conducted in all studies reported here in this chapter. Ultimately an intervention is effective if it achieves the goal of increasing or decreasing targeted behavior. It is important to include ongoing assessment of the intervention effects and be ready to change the intervention should it not produce the desired outcome.

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Chapter 8
Assistive Technology for People with Alzheimer's Disease

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Introduction

Alzheimer's disease is the most common neurodegenerative disease in the industrialized world. It is characterized by a slowly progressing loss of cognitive functions that ultimately lead to dementia and death. Alzheimer's disease accounts for 60–80 % of all dementias, although most people with dementia often evidence brain abnormalities indicative of more than one type of dementia (Schneider et al. 2007). The diagnosis of dementia is based on cognitive or behavioral (neuropsychiatric) criteria as recommended by the National Institute on Aging-Alzheimer's Association workgroups (McKhann et al. 2011). These workgroups have also provided criteria for classifying individuals with dementia caused by Alzheimer's disease. Core clinical criteria have been developed for Probable Alzheimer's Disease dementia and Possible Alzheimer's Disease dementia for use in clinical settings (McKhann et al. 2011; see Tables 8.1 and 8.2). A third classification—Probable or Possible Alzheimer's Disease dementia with evidence of the Alzheimer's Disease pathophysiological processes—is currently used only for research purposes.

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Table 8.1 National Institute on Aging-Alzheimer's Association criteria for all-cause dementia

Dementia is diagnosed when there are cognitive or behavioral (neuropsychiatric) symptoms that:
1. Interfere with the ability to function at work or at usual activities
2. Represent a decline from previous levels of functioning and performing; and
3. Are not explained by delirium or major psychiatric disorder
4. Cognitive impairment is detected and diagnosed through a combination of (1) history-taking from the patient and a knowledgeable informant and (2) an objective cognitive assessment, either a "bedside" mental status examination or neuropsychological testing. Neuropsychological testing should be performed when the routine history and bedside mental status examination cannot provide a confident diagnosis
5. The cognitive or behavioral impairment involves a minimum of two of the following domains:
a. Impaired ability to acquire and remember new information—symptoms include: repetitive questions or conversations, misplacing personal belongings, forgetting events or appointments, getting lost on a familiar route
b. Impaired reasoning and handling of complex tasks, poor judgment—symptoms include: poor understanding of safety risks, inability to manage finances, poor decision-making ability, inability to plan complex or sequential activities
c. Impaired visuospatial abilities—symptoms include: inability to recognize faces or common objects or to find objects in direct view despite good acuity, inability to operate simple implements, or orient clothing to the body
d. Impaired language functions (speaking, reading, and writing)—symptoms include: difficulty in thinking of common words while speaking, hesitations; speech, spelling, and writing errors.
e. Changes in personality, behavior, or comportment—symptoms include: uncharacteristic mood fluctuations such as agitation, impaired motivation, initiative, apathy, loss of drive, social withdrawal, decreased interest in previous activities, loss of empathy, compulsive or obsessive behaviors, socially unacceptable behaviors

In terms of prevalence, about 5.4 million people in the USA have a current diagnosis of Alzheimer's disease; with 5.2 million aged ≥65 years (Hebert et al. 2003) and 0.2 million aged <65 with a early-onset of Alzheimer's disease (Alzheimer's Association 2006). According to Hebert et al. (2003), this translates to 1 in 8 people aged ≥65 years and almost half of those aged ≥85 years having the disease. Of the 5.2 million aged ≥65 years with the disease, 3.4 million are women, i.e., almost two thirds are women. Given that there is no gender difference in age-specific incidence of Alzheimer's disease (Fitzpatrick et al. 2004; Kukull et al. 2002), the increased prevalence of the disease in women is accounted for by the fact that, in general, women live longer than men (Hebert et al. 2001a, b; Seshadri et al. 1997). The estimated annual incidence in the USA is projected to double by 2050—from one new case every 69 s to one every 33 s (Corrada et al. 2010; Hebert et al. 2001a, b). If no great medical breakthroughs intervene, by 2050, the number of people aged ≥65 years with Alzheimer's disease will increase from 5.2 million to an estimated 11 to 16 million (Hebert et al. 2003).

The disease can manifest in people in different ways and progress at different rates. Table 8.3 presents the most common signs that a person may have Alzheimer's disease (www.alz.org/10signs). These common symptom patterns gradually worsen with time and as the disease progresses there is clear decline in the person's cognitive and functional abilities. The most visible functions that decline

Table 8.2 National Institute on Aging-Alzheimer's Association criteria for probable and possible Alzheimer's disease dementia

Probable AD dementia: Core clinical criteria

Probable AD dementia is diagnosed when the patient

1. Meets criteria for dementia described earlier in the text, and in addition, has the following characteristics:
   A. Insidious onset. Symptoms have a gradual onset over months to years, not sudden over hours or days;
   B. Clear-cut history of worsening of cognition by report or observation; and
   C. The initial and most prominent cognitive deficits are evident on history and examination in one of the following categories.
      a. Amnestic presentation: It is the most common syndromic presentation of AD dementia. The deficits should include impairment in learning and recall of recently learned information. There should also be evidence of cognitive dysfunction in at least one other cognitive domain, as defined earlier in the text
      b. Nonamnestic presentations:
      - Language presentation: The most prominent deficits are in word-finding, but deficits in other cognitive domains should be present
      - Visuospatial presentation: The most prominent deficits are in spatial cognition, including object agnosia, impaired face recognition, simultanagnosia, and alexia. Deficits in other cognitive domains should be present
      - Executive dysfunction: The most prominent deficits are impaired reasoning, judgment, and problem solving. Deficits in other cognitive domains should be present
   D. The diagnosis of probable AD dementia ***should not*** be applied when there is evidence of (a) substantial concomitant cerebrovascular disease, defined by a history of a stroke temporally related to the onset or worsening of cognitive impairment; or the presence of multiple or extensive infarcts or severe white matter hyperintensity burden; or (b) core features of Dementia with Lewy bodies other than dementia itself; or (c) prominent features of behavioral variant frontotemporal dementia; or (d) prominent features of semantic variant primary progressive aphasia or nonfluent/agrammatic variant primary progressive aphasia; or (e) evidence for another concurrent, active neurological disease, or a non-neurological medical comorbidity or use of medication that could have a substantial effect on cognition.

Possible AD dementia: Core clinical criteria

A diagnosis of possible AD dementia should be made in either of the circumstances mentioned in the following paragraphs.

Atypical course

Atypical course meets the core clinical criteria in terms of the nature of the cognitive deficits for AD dementia, but either has a sudden onset of cognitive impairment or demonstrates insufficient historical detail or objective cognitive documentation of progressive decline,

Or

Etiologically mixed presentation

Etiologically mixed presentation meets all core clinical criteria for AD dementia but has evidence of (a) concomitant cerebrovascular disease, defined by a history of stroke temporally related to the onset or worsening of cognitive impairment; or the presence of multiple or extensive infarcts or severe white matter hyperintensity burden; or (b) features of dementia with Lewy bodies other than the dementia itself; or (c) evidence for another neurological disease or a non-neurological medical comorbidity or medication use that could have a substantial effect on cognition

Table 8.3 The Alzheimer's Association's 10 warning signs and symptoms of Alzheimer's disease

1. *Memory loss that disrupts daily life*

   One of the most common signs of Alzheimer's is memory loss, especially forgetting recently learned information. Others include forgetting important dates or events; asking for the same information over and over; increasingly needing to rely on memory aids (e.g., reminder notes or electronic devices); or family members for things they used to handle on their own

2. *Challenges in planning or solving problems*

   Some people may experience changes in their ability to develop and follow a plan or work with numbers. They may have trouble following a familiar recipe or keeping track of monthly bills. They may have difficulty to concentrate and take much longer time to do things than they did before

3. *Difficulty in completing familiar tasks at home, at work, or at leisure*

   People with Alzheimer's often find it hard to complete daily tasks. Sometimes, people may have trouble driving to a familiar location, managing a budget at work, or remembering the rules of a favorite game

4. *Confusion with time or place*

   People with Alzheimer's can lose track of dates, seasons, and the passage of time. They may have trouble in understanding something if it is not happening immediately. Sometimes they may forget where they are or how they got there

5. *Trouble in understanding visual images and spatial relationships*

   For some people, having vision problems is a sign of Alzheimer's. They may have difficulty in reading, judging distance, and determining color or contrast, which may cause problems with driving

6. *New problems with words in speaking or writing*

   People with Alzheimer's may have trouble following or joining a conversation. They may stop in the middle of a conversation and have no idea how to continue or they may repeat themselves. They may struggle with vocabulary, have problems finding the right word or call things by the wrong name (e.g., calling a "watch" a "hand-clock")

7. *Misplacing things and losing the ability to retrace steps*

   A person with Alzheimer's disease may put things in unusual places. They may lose things and be unable to go back over their steps to find them again. Sometimes, they may accuse others of stealing. This may occur more frequently over time

8. *Decreased or poor judgment*

   People with Alzheimer's may experience changes in judgment or decision-making. For example, they may use poor judgment when dealing with money, giving large amounts to telemarketers. They may pay less attention to grooming or keeping themselves clean

9. *Withdrawal from work or social activities*

   A person with Alzheimer's may start to withdraw themselves from hobbies, social activities, work projects, or sports. They may have trouble keeping up with a favorite sports team or remembering how to complete a favorite hobby. They may also avoid being social because of the changes they have experienced

10. *Changes in mood and personality*

    The mood and personalities of people with Alzheimer's can change. They can become confused, suspicious, depressed, fearful, or anxious. They may be easily upset at home, at work, with friends, or in places where they are out of their comfort zone include activities of daily living, such as morning toilet routines, bathing, dressing, simple cooking—making a morning cup of tea or coffee, and/or breakfast. With further progression of the disease, particularly in the final stages, there is loss of ability to communicate, failure to recognize close family members, and loss of ability to move around.

There are no extant treatments for Alzheimer's disease—meaning there is no treatment to stop the brain cells involved in Alzheimer's disease from deteriorating with time. Indeed, research suggests that changes in an individual's brain begins at least 10 years before the first signs of memory loss appears, and by the time a diagnosis of Alzheimer's disease is made, there is no way to slow or stop the disease from progressing. Some drugs may temporarily slow the symptoms of the disease, but only for 6–12 months. At present, aggressive medical management of the disease can significantly improve the quality of life of the individual, especially with early diagnosis (Vickrey et al. 2006; Voisin and Vellas 2009). Holistic management of the disease would require developing a care plan that includes treatments by physicians and other healthcare professionals, use of activity and support groups, adult day care, and supportive counseling. Depending on the stage of progression of the disease, assistive technology can be used to enable and encourage individuals with Alzheimer's disease to reacquire simple skills that will allow them to re-engage with their daily living environment.

Research Review

Daily Living Skills

Given that Alzheimer's disease brings about a progressive decline in memory and cognitive functioning, a practical consequence is that people with this condition face increasing difficulty in attending to their basic personal needs. Engaging in activities of daily living generally becomes frustrating to people as their neurodegenerative condition slowly worsens because they simply cannot remember the sequence of steps needed to initiate and complete activities that they used to do almost automatically. Losing these skills usually results in negative social-emotional effects such as withdrawal, depression, and a general lack of motivation to engage in any activity (Tsuno and Homma 2009; Williams and Tappen 2007, 2008; Wood et al. 2009). Recently, assistive technology has been used to re-engage people with mild to moderate Alzheimer's disease, indicating a small but productive window of opportunity to enhance the quality of life of such people.

Lancioni et al. (2009b) reported three pilot studies in which they assessed the effectiveness of verbal instructions, presented automatically through simple technology, to assist persons with Alzheimer's disease to engage in basic daily activities. In all three studies, the assistive technology included a battery-powered, radio-frequency photocell, light-reflecting paper, and a modified Walkman (changed in later studies to an MP3 player) with a recording of the verbal instructions related to the task being taught. A microprocessor-based electronic control unit, with customized software, included a radio-frequency receiver that responded to the photocell inputs, and a programmable command function that regulated the presentation of the verbal instructions. Using bathroom routine as an example, the control unit initiated a training sequence by activating the Walkman and the first instruction (i.e., sit on the toilet). Following a programmed interval, the control unit activated the Walkman and the second instruction (i.e., take the soap). In taking the soap, the person broke the photocell light beam and this started a programmed, brief interval at the end of which the control unit activated the Walkman and the next instruction (i.e., use the bidet). This instruction started another programmed interval at the end of which the control unit activated the Walkman with a new instruction (i.e., take the towel) and so on until all steps of the task were presented for completion.

In the first study, three persons aged 79–86 years, who functioned within the mild to moderate range of Alzheimer's disease, participated. All three were passive or erratic when asked to perform basic activities of daily living, such as their morning toilet routine, dressing, and simple house chores. However, they were able to complete these activities if support staff verbally provided step-by-step directions. Using the assistive technology described above, they were prompted to follow a bathroom routine consisting of 17 instructional steps, within a nonconcurrent multiple baseline design across participants (Barlow et al. 2009). Results showed their mean percentages of steps performed correctly varied between 16 and 54 during baseline and exceeded 90 during intervention with the assistive [prompting] technology.

In the second study, four persons aged 74–81 years, who functioned within the moderate range of Alzheimer's disease, participated. According to family members, all four had problems in performing activities of daily living. As in the first study, all four of them could perform various occupational activities and household chores if support staff verbally guided them step-by-step. In this study, they were taught a dressing activity that had either 10 or 12 steps, depending on the participant. The same technology as in the first study was used, with the taped verbal instructions customized to match the dressing steps programmed for each individual. Results showed the mean percentages of steps performed correctly by the four participants varied between 14 and 41 during baseline and ranged from 80 to 96 during intervention with the assistive technology.

In the third study, three persons aged 73–81 years, who functioned within the moderate range of Alzheimer's disease, participated. All three participants exhibited problems in performing activities of daily living, but were able to follow step-by-step verbal directions related to those activities. In this study, they were taught table setting in the dining room. The task involved 12 or 14 steps, depending on the ability of the participants. Again, the same technology as in the previous two studies was used, with the taped verbal instructions customized to match the table setting activity programmed for each individual. Results showed the mean percentages of steps performed correctly by the three participants varied between 13 and 49 during baseline and exceeded 80 during intervention with the assistive technology.

These three pilot studies provided preliminary evidence that the use of taped verbal instructions paired with basic technology to control the presentation of these verbal instructions can be effective in helping individuals with Alzheimer's disease to recapture lost daily living skills. The intervention produced fairly large and rapid positive effects across all participants and activities of daily living. Furthermore, minimal support staff time was needed during the assistive technology intervention. The data were strong enough in these three pilot studies to support further development research with this technology-based intervention.

In a series of four studies, Lancioni et al. (2009a) replicated and extended the pilot studies reported by Lancioni et al. (2009b). They used the same technology as in the pilot studies. In the first study, four persons aged between 59 and 85 years who functioned within the mild to moderate range of Alzheimer's disease, participated. While they were all physically capable of engaging in activities of daily living, they increasingly required step-by-step verbal instructions by support staff to do so. In this study, they were taught a 17-step bathroom routine within a nonconcurrent multiple-baselines design across participants. Results showed that the participants were able to independently complete between 34 and 40 % of the steps prior to training, and over 90 % during training with the aid of assistive technology. In the second study, two persons aged 81 and 88 years who functioned within the moderate range of Alzheimer's disease, participated. They were taught a 14-step table-setting activity. Results showed that they were able to independently complete 25 and 39 % of the steps prior to training and exceeded 80 and 90 %, respectively, during training with the aid of assistive technology. These two studies effectively replicated the pilot studies by Lancioni et al. (2009b), and provided further validation of the technology.

Three persons, aged between 73 and 81 years who functioned within the moderate level of Alzheimer's disease, participated in the third study. They had problems in carrying out activities of daily living but were able to follow verbal instructions. They were taught a 12-step coffee preparation activity within a nonconcurrent multiple-baseline design across participants. Results showed that they were able to independently perform between 25 and 43 % of the steps prior to training and over 85 % of the steps during training with the assistive technology. The fourth study was essentially to assess maintenance and generalization of skills with one of the individuals who participated in the original pilot study. The same assistive technology set up was established at the individual's home when he was discharged from the rehabilitation center where he learned to use the technology to 90 % proficiency. During the 5-month generalization period at home, he was able to use of the assistive technology to maintain his bathroom routine and dressing skills above 90 %.

Lancioni et al. (2009c) reported three studies that further assessed the effectiveness of verbal instructions presented via technology in enabling individuals with moderate Alzheimer's disease perform activities of daily living, and extended the research to assess the impact of such activity on the individuals' mood. They used the same basic technology as in the Lancioni et al. (2009b) pilot studies. In the first study, two individuals aged 58 and 79 years who functioned within the moderate range of Alzheimer's disease, participated. Both had mild to moderate levels of depression, the cognitive capacity to follow verbal directions and motor control to perform activities of daily living. They were taught a 12-step coffee preparation activity within a multiple baseline design across participants. In addition to recording their performance on the coffee preparation activity, their mood (indices of happiness) was videotaped during the activity and parallel nonactivity periods for later coding. Results showed the participants independently completed 33 and 55 % of the steps prior to training and over 90 % during training with assistive technology. Their mean percentages of intervals with indices of happiness were about 35 and 11 during the coffee preparation activity and 4 and 2 during the parallel nonactivity trials.

In the second study, two ladies aged 59 and 73 years and functioning within the moderate range of Alzheimer's disease, participated. One had moderate and the other mild depression, but each had the cognitive capacity to follow verbal directions and motor control to perform activities of daily living. They were taught a 20-step personal make-up activity within a nonconcurrent multiple-baseline design across participants. Results showed the participants independently completed 63 and 30 % of the steps prior to training and over 90 % during training with assistive technology. Their mean percentages of intervals with indices of happiness were about 19 and 14 during the make-up activity and about 2 during the parallel nonactivity trials. Three ladies, aged between 58 and 72 years who functioned within the moderate range of Alzheimer's disease, participated in the third study. They were taught two activities, the 20-step personal make-up and a 16-step tea preparation. Results showed the three ladies were able to rapidly learn and perform both activities and that their mood was much higher while they were engaged in the two activities when compared to parallel nonactivity trials.

Lancioni et al. (2009e) extended the research base for the use of the verbal instructional technology and its effects on the mood of the participants. In the first study, six individuals aged between 68 and 79 years who functioned within the moderate range of Alzheimer's disease, participated. They were taught a 22-item snack preparation and sharing activity within a nonconcurrent multiple-baseline design across participants. Results showed the participants independently completed 25–60 % of the steps prior to training and 70 % to over 90 % during training with assistive technology. The participants' mean percentages of intervals with indices of happiness ranged from 4 to 22 during the activity trials and from 1 to 7 during the parallel nonactivity trials. In the second study, three men aged 66–76 years who functioned within the mild to moderate range of Alzheimer's disease, participated. They were taught a 16-step shaving activity within a nonconcurrent multiple baseline design across participants. Results showed the men independently completed 30–50 % of the steps prior to training and from close to 70 % to over 90 % during training with assistive technology. For two of the men, the mean percentages of intervals with indices of happiness were almost 7 and 4 during the activity trials and 2 and 0 during the parallel nonactivity trials. For the other man, the mean percentages of intervals with indices of unhappiness were almost 3 during the activity trials and 25 during the parallel nonactivity trials.

Lancioni et al. (2010b) further extended this line of research on the use of verbal instructions and support technology in two additional studies. In the first study, seven individuals aged 61–83 years who functioned within the moderate range of Alzheimer's disease, participated. They were taught either the 12-step coffee preparation activity or the 16-step table setting activity within a nonconcurrent multiple baseline design across participants. Results showed the participants independently completed 30 and 55 % of the steps prior to training and over 85 % during training with assistive technology. Their mean percentages of intervals with indices of happiness ranged from 5 to 20 during the coffee preparation and table-setting activities, and from 2 to 10 during the parallel nonactivity trials. In the second study, four individuals aged 73–86 years who functioned within the moderate range of Alzheimer's disease, participated. They were taught two new tasks, a 20 to 24-step fruit salad preparation activity and a 26 to 34-step vegetable salad preparation activity, with the number of steps adjusted to their level of competence. Each participant was provided training within a multiple probe design across activities (Barlow et al. 2009). Results showed the participants rapidly learned the steps of the tasks by using the assistive technology and their mood, as ascertained by indices of happiness, increased while they were engaged in the activities.

Lancioni et al. (2010a, b) assessed whether verbal-instruction technology can help individuals with mild or moderate Alzheimer's disease to maintain their relearned performance of activities of daily living. Nine individuals, aged 58–81 who functioned within mild to moderate range of Alzheimer's disease, participated. Using essentially the same technology as in the initial study (Lancioni et al. 2009b), but with an MP3 player replacing the Walkman, the participants were taught one of the tasks used in previous studies (i.e., make-up, snack, table setting, tea, shaving, and coffee). The tasks included between 12 and 22 steps. In addition, to assess the impact of the activities on indices of happiness, nonactivity observation trials were conducted parallel to the activity trials according to an alternating treatments design (Barlow et al. 2009). Maintenance was assessed once the nine participants had reestablished their performance on these activities. The results showed maintenance of performance across all nine participants for a minimum of 5 months and a maximum of 14 months. This was the first study to demonstrate maintenance of reestablished performance of activities of daily living by individuals with Alzheimer's disease.

In the final study in this series, Lancioni et al. (2012) expanded the instructional choices to include technology-aided pictorial cues to support the performance of activities of daily living by individuals with Alzheimer's disease. The technology used in this study used both verbal and pictorial cues. The technology with verbal instructions consisted of (a) a microprocessor-based electronic control unit with specific software, (b) an amplified MP3 player with USB pen drive connection, (c) a pen containing the recording of the verbal instructions related to the activity to be performed, and (d) optic sensors. There were two tables, one with the activity items and the other for the execution of the activity. This technology worked as described in previous studies (e.g., Lancioni et al. 2009b). The technology with pictorial cues included (a) a computer with specific software, (b) two screens with speakers located on the items' desk and the implementation desk, respectively, (c) optic sensors, and (d) pictorial (photographic) images/cues appearing on the screens. At the start of an activity trial, the screen on the implementation desk showed a pictorial cue. This represented the first instruction (e.g., the image of a red container that the participant was to take from the items' desk). In taking the container, the participant activated the optic sensors and caused the appearance of a pictorial cue (marked by an alerting sound) on the screen of the items' desk. This cue represented the second step of the task (e.g., place the container on the tablecloth) that the participant was to perform at the implementation desk. After a programmed interval (e.g., 20 s), a new pictorial cue signaled by an alerting sound appeared on the screen of the implementation desk where the participant was. This cue represented the third instruction (i.e., an item that the participant was to take from the items' desk). The procedure continued the same way through the different steps of the activity.

Three women, aged 73–79 years who functioned at a moderate level of Alzheimer's disease, participated in this two-part study. In Part I, an alternating treatments design (Barlow et al. 2009) was used with each participant to compare the assistive technology using pictorial cues plus verbal instructions with the existing verbal instructions strategy. Two of the women had the pictorial cues plus verbal instructions for cleaning/sorting kitchen items and the verbal strategy for preparing vegetables. The third woman had the opposite strategy-activity combination. In Part II, an alternating treatments design was used with each participant to compare the assistive technology with pictorial cues alone and with the verbal instructions strategy. One woman used the pictorial cues for preparing fruit juice and the verbal strategy for arranging the items to serve fruit juice. The remaining two women had the opposite strategy-activity combination. Verbal and physical prompting by a research assistant occurred if the participants failed to respond to a cue/instruction for 10–20 s (during intervention) or failed to perform a step appropriately (during both baseline and intervention). In addition, a social validation assessment was undertaken, in which university psychology students rated the assistive technology with pictorial cues versus the verbal instructions on a five-item questionnaire. Results showed the assistive technology with pictorial cues and the verbal instructions were equally effective with all the three women, reaching means of over 90 % for independent performance. The social validation assessment favored the pictorial cues in terms of respect for the participants' dignity and favored the verbal instructions in terms of practicality.

Other cognitive assistive technologies, coupled with some form of artificial intelligence, have been used to support people with various disabilities (Intille 2004). For example, Cognitive Orthosis for Assisting aCtivities in the Home (COACH) uses artificial intelligence to autonomously guide an individual with dementia through a specific activity of daily living skill, such as hand washing, by using audio and/or audio–video prompts (Mihailidis et al. 2004). In a recent study, Mihailidis et al. (2008) tested the effectiveness of COACH in assisting six individuals with moderate to severe dementia in hand washing within a single-subject reversal design (Barlow et al. 2009). Results showed that, on average, individuals with moderate dementia were able to complete an average of 11 % more hand washing steps independently and required 60 % fewer interactions with a human caregiver when COACH was in use. In addition, four of the six individuals achieved complete or almost complete independence.

In summary, based on current evidence from evaluations using single-case experimental designs, verbal instructions and pictorial cues supported by technology appear to be viable methods for helping people with mild or moderate Alzheimer's disease reengage in activities of daily living. Moreover, activity engagement may help some of these people improve their mood and show increased signs of happiness. Although very encouraging, the current data have several limitations, and caution should be exercised in making general conclusions regarding the use of these instructional strategies with new activities, the strategies that might be used to help participants with behavioral deterioration due to their Alzheimer's disease, and the conditions necessary for mood benefits. Only one study assessed maintenance of training gains over time, but with only a small number of participants. Given that Alzheimer's disease is a degenerative condition, determining how long the participants can remain reengaged in activities of daily living with the support of assistive technologies is a very important consideration and worthy of future research.

Music Stimulation

There are few intervention strategies that are reliably successful for people in the severe stage (and possibly in the lower end of the moderate stage) of Alzheimer's disease that not only reduce behavioral disturbances, but also improve participation and mood/happiness. Music is an exception in that it appears to have a calming effect on most people with Alzheimer' disease and lessens their agitation, anxiety, and depression (Guetin et al. 2009; Janata 2012; Raglio et al. 2010; Raglio and Giannelli 2009). Music has been used in a number of ways with this population. For example, some studies programmed active involvement of a therapist or professional musician in playing music directly to the participants (Cevasco 2010; Chatterton et al. 2010; Gotell et al. 2009). Other studies have resorted to the simple presentation of prerecorded music (Wall and Duffy 2010; Ziv et al. 2007). In yet other studies, the music material was the same for all participants and its selection was based on its presumed calming/soothing qualities (Casby 1994; Ho et al. 2011), or the music was individualized and its selection was based on the participants' preferences (Gerdner 1993, 2000; Hicks-Moore and Robinson 2008).

Given that music intervention can be a useful resource in programs for persons with moderate and severe Alzheimer's disease, we need to consider the role of the participant during the music session. In many studies, participants in the severe or lower end of the moderate stage of Alzheimer's disease, who show extensive physical and behavioral decline accompanied by forms of withdrawal and depression, are generally considered as having a passive role in the selection of the music being played. That is, they are expected to enjoy music periods arranged for them by a support staff or family members (Chatterton et al. 2010; Raglio et al. 2010; Wall and Duffy 2010; Ziv et al. 2007). An active role, with the participants regulating the music stimulation through simple responses, however, could be useful in terms of (a) allowing them to exercise a form of adaptive behavior considered relevant to counter their detachment from the immediate environment, and (b) providing them a more positive and socially acceptable image (Giordano et al. 2010; Raggi et al. 2007; Smith-Marchese 1994). One possibility for promoting a more active role for these people might be through the use of basic assistive technology that allows the person to control the initiation and continuation of the music stimulation via simple to perform motor responses (Tai et al. 2008). Recent studies of music stimulation for people with Alzheimer's disease have adopted this approach.

Lancioni et al. (2013e) assessed the differential effects and social rating of an active music condition, in which people with Alzheimer's disease regulated their music input, and a passive music condition, in which music stimulation was prearranged and available continuously. The active (self-regulated) and passive stimulation sessions were preceded and followed by baseline (nonstimulation) sessions. The technology used during the baseline and the active intervention sessions included a microswitch, a laptop computer, and an interface to connect the microswitch to the computer. An individual could use a pressure microswitch on the table in front of him or her or a pressure microswitch in his or her hand depending on which of the two response options appeared easier to use. During the active intervention sessions, the computer served to (a) present a 15-s song segment after each microswitch response (successive responses allowed the individual to listen to the entire song), (b) present a verbal encouragement to activate the microswitch if the individual failed to produce a new response within about 15-s from the end of the previous song segment, and (c) record the microswitch responses. A new response was recorded only if it occurred after the end of the song period following the previous response. During the baseline sessions, the computer served only to record the microswitch activations. A new activation was recorded if this occurred at least 15 s after the previous one (i.e., after an interval comparable to that of the song stimulation used in the active intervention sessions). The music sessions were videotaped and scored for indices of positive participation.

Ten individuals, aged 78–84 years who functioned at severe stage (seven participants) or at the lower end of the moderate stage of Alzheimer's disease, participated in this study. Nine of them had mild to severe depression. They participated in 3 to 7 music stimulation sessions a day. The active condition sessions showed an increase in the patients' indices of positive participation (e.g., singing or music-related movements, and smiles) similar to that observed in the passive condition sessions. Social validity ratings by university students favored the active condition in terms of suitability, respect of individuals' dignity, independence, and practicality. This initial study indicated that active music stimulation could be a viable, effective, and socially preferable method of engaging individuals with Alzheimer's disease.

Lancioni et al. (2013b) continued this line of research by (a) comparing the effects of an active, technology-supported music condition to that of a passive music condition with additional participants and (b) conducting a social validation assessment of the two conditions with raters who had practical experience in the care and rehabilitation of individuals with multiple disabilities. Six individuals, aged between 76 and 89 years who functioned at the severe stage of Alzheimer's disease, participated in this study. The assistive technology and methodology was the same as in the initial study (i.e., Lancioni et al. 2013e). In the active condition, the individuals used a simple hand response and a microswitch to self-regulate music stimulation. In the passive condition, music was automatically provided without input from the participants. The active and passive music stimulation sessions were preceded and followed by control (i.e., no music) sessions. Results showed an increase in the individuals' indices of positive participation (e.g., singing or music-related movements, and smiles) during the active condition, which was greater than that observed in the passive condition for five of the six individuals. Social validity ratings favored the active condition on suitability, respect and dignity, independence, and practicality of the technology.

Lancioni et al. (2013c) further extended the comparison of active music stimulation versus passive music stimulation with seven individuals, aged between 75 and 90 years and functioned at the severe or low moderate stage of Alzheimer's disease. The assistive technology and methodology was the same as in the initial study (i.e., Lancioni et al. 2013e). As in the previous two studies, in the active condition the participants used a simple hand response and a microswitch to self-regulate music stimulation and in the passive condition, they automatically received music stimulation. Results showed an increase in the participants' indices of positive participation during both active and passive music conditions. However, the positive participation in the active condition was greater than in the passive condition for five of the seven participants. Of the other two participants, one showed comparable positive participation across the two conditions and the other showed a smaller increase in the active condition.

Lancioni et al. (2013a) continued the assessment of active versus passive music stimulation on positive participation of individuals with Alzheimer's disease. Eleven individuals, aged between 65 and 95 years who functioned in the severe and low-moderate stage of Alzheimer's disease, participated in the study. Both music conditions relied on the display of music/song videos on the computer screen. The assistive technology and methodology was the same as in the initial study (i.e., Lancioni et al. 2013e). In the active condition, the participants used a simple hand response and a microswitch to control music stimulation inputs and in the passive condition, music stimulation was automatically presented throughout the sessions. Results showed that 6 of the 11 participants had higher levels of positive participation in the active condition, with the remaining five showing no difference between the two conditions.

In summary, these four studies suggest that self-regulated music is equal to or more effective than the passive condition, in which the music is automatically presented, in promoting positive engagement by individuals with Alzheimer's disease. Furthermore, the self-regulated music condition appears to have greater social validity than the passive music condition. This suggests families and support staff of individuals with Alzheimer's disease, especially those who are at the severe stage of the disorder, may want to consider encouraging the individuals to self-regulate their music engagement. Of course, this option would require obtaining some hardware technology (i.e., microswitch and interface) and a basic software program to coordinate the functioning of the hardware with the presentation of stimulation events and computer reminders (Borg et al. 2011). It would also require extra investment of time by family and support staff to (a) identify a suitable response and a matching microswitch, (b) establish microswitch responding, which is essential for a satisfactory outcome of the condition, and (c) set up effective reminders to help the individuals refocus their attention in case of response delay or response failure (Guetin et al. 2009; Janata 2012; Labelle and Mihailidis 2006; Mihailidis et al. 2007; Parisi et al. 2011).

Indoor Travel

Individuals with Alzheimer's disease evince disorders in spatial orientation and travel (Cherrier et al. 2001; Gadler et al. 2009; Grossi et al. 2007; McGilton et al. 2003; Provencher et al. 2008; Rainville et al. 2001). The severity of these disorders normally varies with the progression of the disease. For example, in the very early stages of the disease, the person may show spatial orientation disorders in unfamiliar environments. As the disease gradually progresses, orientation disorders extend into their familiar environments and ultimately into their home or other daily contexts with extensive negative implications on activity engagement, basic personal independence, self-assurance, and social status (Benge et al. 2011; McGilton et al. 2003; Nolan et al. 2001; Passini et al. 2000; Rainville et al. 2001).

Behavioral strategies commonly used to address these disorders involve the sequencing of spatial cues that can be taught through backward chaining programs (Gadler et al. 2009; Passini et al. 2000). Spatial cues may be viewed as salient stimuli (e.g., colors and photos) that are used to help the person discriminate and recognize specific areas, such as room entrances, that are relevant for his or her orientation and functional travel (Gibson et al. 2004; Nolan et al. 2001). Behavioral strategies work well with individuals who are in the initial stages of Alzheimer's disease, but they appear to be less effective as the disease progresses, with concomitant memory loss (Provencher et al. 2008). Furthermore, the use of backward chaining is very labor intensive (Brooks et al. 1999; Brunsdon et al. 2007).

Technology-based orientation programs may provide a viable alternative to the use of behavioral strategies. For example, assistive technology approaches have been successfully used with individuals with intellectual and visual disabilities (see Lancioni et al. 2010a). A basic form of orientation technology could entail the use of direction auditory cues, that is, cues that are repeated with a certain regularity to direct the individual to the target destination (Lancioni et al. 2001, 2007; Martinsen et al. 2007). Recently, three studies have evaluated the use of technology-based orientation programs to support indoor travel by individuals with mild to moderate Alzheimer's disease.

In the first study, Lancioni et al. (2011d) assessed whether individuals with Alzheimer's disease can learn to use a basic orientation technology to reach different rooms in their day center. Seven rooms at the day center were designated as the target destinations. The orientation technology included a sound source at each of the destinations and a portable control system to activate and deactivate each of those sources. Every source was a battery-powered, two-track recording/playing device. The recordings available within each track consisted of short sentences encouraging the individual to walk and find the destination (see Lancioni et al. 2008). Those sentences were played as the source was activated through the portable control system, which included destination and stop keys. Pressing a destination key activated the sound source available at that destination, which in turn played the aforementioned sentences. At the start of each instance of travel, the individual was informed as to the destination he or she was supposed to reach and generally provided with some material to bring along for the person to meet at that destination. During all sessions in which the orientation system was used, the aforementioned announcement was followed by the activation of the sound source of the target destination. The source was deactivated as soon as the individual arrived.

Three individuals, aged 73–83 years who functioned at mild to moderate stage of Alzheimer's disease, participated in this study. All three individuals attended a day center that engaged them in various supervised activities. They seemed to enjoy traveling across the different rooms of the day center and meeting different staff people. However, their ability to independently reach appropriate room destinations was limited for two of them and totally negligible for the other. The distance between room destinations ranged from 5 to 13 m, with a mean distance of about 9 m per destination. One training session was provided per day, 6 days a week. Results showed that all three individuals were successful in using the technology to orient their travel and find the rooms correctly. A social validation assessment, in which university psychology students were asked to rate the individuals' travel performance with the assistive technology versus staff assistance, provided generally more positive scores for the technology-assisted performance. These results suggest that this orientation system may be effective in helping individuals with Alzheimer's disease reach their target destinations within a day center successfully.

In the second study, Lancioni et al. (2013d) (a) replicated the use of the assistive technology with auditory cues with new participants, (b) compared the effects of this program with light cues, i.e., strobe lights were used instead of the auditory cues, and (c) conducted a social validation of the two programs (i.e., assistive technology with auditory versus light cues). Five individuals, aged 72–80 years who functioned at the lower end of the moderate stage of Alzheimer's disease, participated in this study. The results replicated the success of the auditory program with five new participants, thus confirming the findings of Lancioni et al. (2011d). Furthermore, the program with the light cues was also very successful with the same participants, thus giving families and support staff a choice of two types of cues, depending on the preference of the participants. Finally, in the social validation study, light cues were rated higher than the auditory cues.

In the third study, Lancioni et al. (2013f) assessed the effectiveness of a commercially available, basic doorbell system with sound and light cues to support indoor travel instead of the custom-built technology used in the previous two studies. The system consisted of a receiver that was located at the destinations and a transmitter used by the research assistant. The receiver emits various types of sounds from which the research assistant chooses the one considered most suitable for the individual and the environment. The sound emission can be combined with strobe light flashes to provide additional orientation cues for the individual (see Lancioni et al. 2013d). The transmitter allows the research assistant to operate the receiver from any position, without interfering with the individual's travels. Four individuals, aged 71–89 who functioned at the moderate stage of Alzheimer's disease, participated in this study. Results showed the percentages of correct travels of two individuals matched the data of the most successful participants involved in previous studies with more sophisticated technology. The percentages of the other two participants were lower than those obtained in previous studies, but were still practically relevant.

In summary, individuals with mild to moderate Alzheimer's disease can engage in purposeful indoor travels using either customized assistive technology-based auditory or visual cues, or standard doorbell system paired with a transmitter and receiver. The data are from a limited number of participants, thus precluding any general extrapolation from these findings. However, the data do suggest that customized as well as simple technology-aided programs may afford some individuals the opportunity for independent indoor travel.

Phone Calls

The cognitive changes associated with Alzheimer's disease lead to progressive performance declines in the individual's instrumental activities of daily living, such as communication with distant partners (i.e., family members and friends) via telephone (Ala et al. 2005; Loewenstein et al. 1995; Nygard and Starkhammar 2003). For example, the progressive difficulties that individuals with Alzheimer's disease encounter in using the telephone are so well known that telephone management has been included as an item in standardized assessments of individuals with suspected dementia (Ala et al. 2005). The negative practical and social/emotional implications of those difficulties (i.e., their influence in further isolating individuals with Alzheimer's disease) are obvious and the need to find possible solutions to curb their impact is pressing (Nygard and Starkhammar 2003, 2007; Selwyn 2003; Todis et al. 2005). Extant efforts have focused on teaching basic phone skills by using (a) errorless learning methods, and (b) simple-to-use telephone devices (De Joode et al. 2010; Lekeu et al. 2002; Topo et al. 2002).

A computer-aided telephone system was recently developed for people with multiple disabilities that (a) works through a simple microswitch (i.e., a single input device operated with a basic hand response) and (b) does not require the individual to deal with telephone keys, or to remember, retrieve or dial the numbers of the partners that he or she wants to contact (Lancioni et al. 2011a, b). The first activation of the microswitch causes the system to list persons that the participant may be interested in calling. Microswitch activation in relation to a specific person leads the system to place a phone call to that person, thus allowing the participant to have a conversation with him or her. This system was assessed with four participants with visual-motor or visual-motor and intellectual disabilities. Given all participants learned to make phone calls independently, this system may be equally effective with individuals with neurodegenerative conditions. Recently, two studies evaluated the use of computer-aided telephone system to make independent telephone calls by individuals with Alzheimer's disease.

In the first study, Perilli et al. (2012) assessed whether individuals with Alzheimer's disease can make independent phone calls via a computer-aided telephone system. The computer-aided telephone system consisted of a net-book computer, a global system for mobile communication modem (GSM), a microswitch device to enable the participants to activate the computer, an interface connecting the microswitch to the computer, a headset with microphone (allowing the participants to keep the communication utterances of their partners private) and a specifically developed software program. The software program ensured that the computer could present identification names and photos of possible phone conversation partners, according to pre-programmed sequences, and respond to microswitch activations to place phone calls to the selected partners. The microswitch was a simple pressure pad located on the table, in front of the participant, and could be activated with a small hand contact.

With the computer-aided system, the initial microswitch activation triggered the computer to present the participant a list of 7 to 12 relevant partners (i.e., spouse and other family members, long-time friends, and staff) he or she could call. For each partner, the computer verbally presented the name while showing his or her photo or other identification expression (e.g., Peter or your wife?) on the screen. If the participant did not respond within 3–4 s, the computer presented the next photo and related verbal identification (e.g., the photo and name of his or her son), and repeated the aforementioned statement. If the participant responded within 3–4 s, the computer selected the telephone number of that partner and activated a phone call to that partner, leaving his or her photo on the screen, enabling the individual to maintain some form of visual contact with the partner. After the end of the conversation with a partner, or following the impossibility to establish contact (i.e., given a busy signal or a voice message from an answering machine), the individual could activate a microswitch to disconnect the telephone line and make the telephone system ready for a new call.

Four individuals, aged 73–83 years who functioned at the moderate stage of Alzheimer's disease, participated in this study. The study was executed according to a nonconcurrent multiple baseline design across participants (Barlow et al. 2009), with training sessions scheduled once or twice a day. Sessions lasted 10 min if no phone call was active by the end of that period or until the call was connected, if it was active by the end of the 10-min period. Within each session, a research assistant recorded the (a) total number of phone calls and whether they were made independently (i.e., by the participant without any external prompting) (b) number of phone calls which were met with the answer of the target partner, and (c) length of the conversations. Results showed the individuals made no independent phone calls prior to the training, and between two and five calls to family members and friends using the computer-aided telephone system, for an average of 5–6 min per call following training.

In the second study, Perilli et al. (2013) replicated the use of the computer-aided telephone system with additional participants with Alzheimer's disease and assessed the social validity of the assistive technology system compared to a condition of conventional telephone assistance. Five individuals, aged 73–89 years, who functioned in the moderate range of Alzheimer's disease, participated in the study. They were divided into two groups and exposed to intervention according to a nonconcurrent multiple baseline design across groups. All individuals started with a baseline in which the technology was not available followed by an intervention in which the technology was used. All learned to use the new telephone system and made phone calls independently to a variety of partners, including family members, friends, and caregivers. A social validation assessment, in which care and health professionals working with persons with dementia were asked to rate the individuals' performance with the technology when compared to staff-assisted telephone calls, showed generally higher ratings for the computer-aided telephone system.

In summary, there is preliminary evidence that a computer-aided telephone system can assist individuals with Alzheimer's disease to make phone calls independently. The individuals acquired this ability relatively easily and used it to communicate with their distant partners successfully. Enabling this communication opportunity can be instrumental in helping these individuals to maintain their social contacts and reduce social withdrawal (Lancioni et al. 2011a; Stock et al. 2008). The computer-aided telephone system appears highly functional for restoring instrumental communication skills because it guides the participant through the range of partners available for phone contact and allows him or her to select the one to call with a simple microswitch response (i.e., it helps the participant avoid all the difficulties connected with memory—retrieving or dialing telephone numbers) (Greig et al. 2008; Johnson et al. 2009; Wehman et al. 2009).

Wayfinding and Wandering

Even in the early stages of Alzheimer's dementia, individuals begin to lose their mastery of daily life autonomy, especially in terms of attentional control and spatial orientation (e.g., getting lost or being unable to ascertain where a person is in physical space). For example, there appears to be a direct correlation between attentional control and spatial navigation, with the decay in attentional control increasing spatial navigation problems (Chiu et al. 2004). There is an emerging technology, but currently not fully realized in practice, that deals with virtual reality and virtual environments that can be used to slow the progression of the loss of autonomy. Assistive technology can be helpful to people with Alzheimer's dementia when they get spatially disoriented either in their own house or in the community. Engaging these individuals at the earliest possible opportunity following a diagnosis of Alzheimer's disease in virtual reality programs may act as a protective factor for their daily life autonomy. Recent virtual reality work has focused on training and using cognitive skills that are still likely to be intact in people with early-stage Alzheimer's disease (Zetzsche et al. 2012), or by focusing on the individual's residual skills by restructuring tasks so that the remaining abilities can be used in place of those that are most impaired (LoPresti et al. 2004), thus enabling engagement in selected tasks autonomously. For example, training in wayfinding can be instituted in virtual reality for those individuals who are disoriented and either get lost or cannot use environmental cues to get home. By building a virtual reality that focuses the individual's attention to salient and autobiographically important landmarks, and then having the individual practice routes between them, will enable the person to build and rely on a more resilient sensorimotor representation of their environment. The purpose of wayfinding technologies is to enable people to maximize their cognitive abilities in the face of neurodegeneration.

Wandering is another characteristic of some individuals with Alzheimer's disease and other dementias (Algase et al. 2009a; Aud 2004). Wandering may be related to spatial disorientation (as discussed above), or can be an aimless activity without any apparent goal (Algase et al. 2010; Wick and Zanni 2006). Of course, individuals with Alzheimer's disease may use wandering to increase stimulus input in a socially-mediated or self-stimulatory manner (Heard and Watson 1999; Lucero et al. 2001), or as a strategy to reduce stress, anxiety or other situations of uneasiness and malaise (Algase et al. 2009b; Ayalon et al. 2006). On the assumption that wandering may be related to stimulus deprivation, some successful interventions have focused on enhancing sensory stimulation, such as music (Sung and Chang 2005), and aromatherapy (Lin et al. 2007). In a recent study, both a coloring activity and music stimulation were reported to reduce wandering in a man with severe Alzheimer's disease (Lancioni et al. 2011c).

There are various assistive technology systems that enable caregivers to ensure individuals with Alzheimer's disease do not wander outside of a safe environment. For example, Care Watch can be used to prevent individuals with cognitive impairments from unintentionally exiting their home, especially at night (Rowe et al. 2007). The system can be programmed for use both during daytime and nighttime. For example, during the daytime mode, an alarm alerts a family member or support staff when the individual exits an outside door, and during the nighttime mode, the alarm alerts them when the individual gets off the bed. This is a relatively unobtrusive system but does require continuous monitoring by caregivers. In a small controlled trial, caregivers found the device to be very reliable and useful, affording them "peace of mind" that the system will alert them if the individual gets out of bed at night (Spring et al. 2009).

In summary, little research on assistive technology is available to guide the design and implementation of intervention to improve wayfinding and prevent wandering, but what there is, shows promise.

Urinary Control

People with Alzheimer's disease and other dementias often experience urinary incontinence and toileting problems (Adkins and Mathews 1997; Hagglund 2010; Harari and Igbedioh 2009; Offermans et al. 2009). In general, cognitively competent older people can use a number of strategies to overcome these problems, including habit training, bladder and pelvic muscle exercise, and biofeedback (Adkins and Mathews 1997; Baigis-Smith et al. 1989; Goode et al. 2010). However, older people with Alzheimer's disease and other dementias may not be able to benefit from using these strategies due to their impaired cognitive functioning as well as their reduced adaptive, practical and organizational skills (Hagglund 2010; Hutchinson et al. 1996; Wai et al. 2008).

The use of urinary alarm systems offers a possible alternative strategy for individuals with Alzheimer's disease. In this system, the urinary alarm is activated as soon as the individual begins to release urine and this alerts the support staff to prompt the individual to stop urinating and to complete the urination in the toilet. Frequent pairing of early stages of urination and prompts to complete it in the toilet often increases the individual's awareness of the need to urinate. For those in the early stages of dementia, the repeated experience of alarm signals in relation to the first drops of urine might also help re-discover bladder tension and foster some spontaneous toileting requests (Lancioni et al. 2002). For example, Lancioni et al. (2011e) evaluated the use of such a system with three individuals with Alzheimer's. In this study, the urine alarm system presented auditory and vibratory signals as soon as the individual began to release urine, thus alerting staff who prompted and encouraged the individual to stop urinating and accompany the staff member to the toilet to void. The staff member provided positive social attention when the individual completed urination. Results showed that the use of the alarm system and staff members' prompts were effective in helping the three individuals reduce their large urinary accidents to zero or near zero levels. Self-initiated toileting, which was minimal prior to the use of the urine alarm, accounted for nearly 35, 50, and 75 % of the patients' toileting occasions during the intervention. Social validation assessment by 52 staff members rated the use of the urine alarm system above the use of timed toileting as the preferred method for managing urinary incontinence in individuals with Alzheimer's disease.

In summary, the use of simple assistive technology devices, such as a urine alarm, has the potential to be beneficial to individuals with Alzheimer's disease because it enables them to increase awareness of bladder tension, the need for voiding urine, and having the time to void in the toilet. Avoiding urinary incontinence increases their social acceptability and enhances self-image.

Communication

A common finding with people who are diagnosed with Alzheimer's disease is a gradual deterioration of communication—as their disease progresses, memory deficits increase and lead to repetitive questions and decreased verbalizations. During the later stages of the disease, the individuals successively engage in echolalia, perseverative speech, incoherent vocalization, and eventually mutism (Bourgeois and Hickey 2009). Even with this deterioration in speech, the individuals may idiosyncratically maintain other skills that can be selectively accessed to help them maintain a reasonable quality of life. For example, some of them retain some forms of long-term memory (e.g., episodic, procedural) that can be utilized in a functional manner.

Residual long-term memory can be enhanced with assistive technology and utilized to increase communication by individuals with Alzheimer's disease. For example, it is a common practice in adult day care centers and nursing homes to use memory wallets and customized short books to increase communication in people who have middle-stage dementia (Hanley and Lusty 1984). In an early study, Bourgeois (1990) evaluated the effectiveness of teaching three individuals with middle-stage Alzheimer's diseases to use a memory wallet as a memory aid when conversing with familiar partners. The memory wallet contained short factual sentences (e.g., names of family members, orientation facts) meaningful to the individuals and accompanying pictures mounted on white paper. They were taught to use these memory wallets in short, twice a week, conversations with a partner, and the training outcomes were assessed within a multiple baseline design across topic areas. Results showed the individuals not only used the memory aid to improve the quality of their conversational content, but also engaged in conversation beyond what was taught. Furthermore, the individuals were able to maintain their enhanced conversational skills at 3- and 6-week follow-ups. In a replication and extension of this study, Bourgeois (1992) demonstrated the clinical utility of memory wallets with nine individuals diagnosed with Alzheimer's disease and other dementias. In this study, three of the nine individuals demonstrated maintenance of enhanced conversational skills for up to 30 months following training.

In a related study, Bourgeois et al. (2001) assessed the generalized effects of providing memory book to individuals with dementia on their conversations with nursing aides. The memory books were customized for each participant in terms of their life and family (autobiographical information), aspects of their daily life at the nursing home, or a current problem. Each page was illustrated with photographs, drawings, or graphics. A total of 66 individuals with dementia (33 each in treatment and control groups) and 66 nursing aides (33 each in treatment and control groups) participated in this study. The nursing aides assigned to the individuals in the treatment group were trained to use the memory book during their interactions with the individuals throughout the day. Bourgeois et al. videotaped and later scored the duration and quality of verbal interactions between participant-nurse aide dyads during 5-min conversations. Results showed improvements on a number of quantitative conversational measures (e.g., duration of speaking, frequency of utterances) between treatment and control conditions, as a function of memory book use. As evident from the frequency of discourse characteristics (e.g., facilitative behaviors), there was a concomitant improvement in the quality of conversations. Social validation assessment by the nursing aides suggested overall improvement in the individuals' quality of life.

In another series of studies, researchers developed personalized reminiscences that can be used to enhance the quality of interactions family and staff can have with individuals diagnosed with dementia, including Alzheimer's dementia. Materials for reminiscence sessions are developed using photos and other memorabilia of the individual, and can often include audio and videotapes. These materials not only act as a memory aid but also enable family members and staff to enhance the quality of interactions with the individual. Effects of reminiscence sessions include increased feelings of positive self-esteem and psychosocial well-being (Lai et al. 2004) and decreased behavioral disturbances (Finnema et al. 2000; Grasel et al. 2003). The underpinning of reminiscence sessions is the finding that long-term memory in individuals with dementia is usually intact even after short-term memory is impaired (Rentz 1995). An advantage of reminiscence is that it can be conducted in a group led by an experienced staff member who knows the individuals well (Wang 2007).

Yasuda et al. (2009) advanced the concept of a personalized reminiscence photo video as a convenient method for reminiscence intervention. They developed photo videos by utilizing a slideshow of personal photos with narration, background music, and pan/zoom visual effects. In this study, 15 individuals with Alzheimer's dementia watched personalized reminiscence photo videos (A), a variety TV show (B) and a TV news program (C), within an ABCA research design. Results showed that 12 of the 15 individuals were more engaged when viewing their personalized reminiscence photo video as compared to the TV show or TV news program, and suggested that personalized reminiscence photo videos may be an effective memory aid.

De Leo et al. (2011) extended this line of research by acquiring autobiographical memory of an individual with Alzheimer's disease via a smart phone. They programmed a smart phone to take pictures at 5-min intervals for 12 h during the day. Each week, these pictures were collated into a video slide show and saved on DVD. The individual and his support staff viewed the DVD on a weekly basis. Results indicated that viewing the DVD assisted the individual to better recall recent events. This approach appears to be very practical, but more data are needed to assess its full potential.

Alm et al. (2004) further developed the concept of personalized reminiscence by developing a fairly sophisticated computer-based multimedia assistive technology as a communication support for people with dementia. Instead of a photo video, they enhanced the system by including personal web pages and scrapbook that could be accessed through an interactive touch-panel display. A preliminary evaluation of the system showed positive ratings by the individuals as well as by staff.

In summary, clinicians and support staff can capitalize on the fairly intact long-term memory of individuals with Alzheimer's disease, especially of those who are in the earlier stages of the disease, to enable them to engage in social communication with support staff and family members. Personalized wallets, personalized reminiscences, personalized reminiscences photo videos, autobiographical memory data collected via a smart phone, or a computer-based multimedia system can be used to enhance the quality of lives of people with Alzheimer's disease or other dementias.

Discussion

There are no extant treatments that can prevent, cure, reverse, or slow the progression of Alzheimer's disease, but there are interventions that can alleviate specific symptoms, reduce suffering, and maximize residual abilities of individuals with the disease. When developing interventions for people with Alzheimer's disease, researchers face the ubiquitous question of whether their proposed treatments are intensive and powerful enough to overcome the ravages of this progressive disease. Even if the interventions do produce change, is the change meaningful in the lives of people with this disease? Assistive technology has been increasingly used to enhance functioning, especially in daily living contexts, by giving the individuals supportive tools that they can use to manipulate their environment in a planned and meaningful manner. While the efforts expended in developing assistive technology tools for people with general cognitive disorders have been extensive, their application specifically to individuals with Alzheimer's disease has been rather limited (LoPresti et al. 2004).

The assistive technology studies dealing with activities of daily living suggest that technology-supported verbal instructions and pictorial cues can be programmed to assist individuals with Alzheimer's disease, especially those at the early stages of the disease. Individuals who participated in these studies learned to use the technology fairly rapidly and maintained the learning over short periods. The studies on technology-supported self-regulation of music are also very encouraging because they suggest individuals with Alzheimer's disease can reengage in leisure skills, even at the severe stage of their illness. The studies on indoor travel are encouraging as well, as they suggest technology-aided travel is possible and can result in secondary benefits, such as social interaction with others along the way and the possibility of employment (e.g., delivering internal mail). The preliminary evidence supporting the use of computer-aided telephone systems in this population suggests that they can open an unexplored world for these individuals. Indeed, with computer-aided telephone system, individuals with Alzheimer's disease can maintain contact with family and friends, thus increasing their social connectedness. There is minimal research on wayfinding, wandering and personal hygiene specifically with people with Alzheimer's disease. There is limited but exciting research on communication systems for people with cognitive impairments, such as those with Alzheimer's dementia. The use of memory wallets, personalized reminiscences, use of smart phones to periodically collect autobiographical data that can later be used in conversations, and computer-based multimedia systems are all very encouraging and may result in viable assistive technologies for this population.

The obvious limitations are that the field of assistive technology for people with Alzheimer's disease is of fairly recent vintage and, thus, very few studies are currently available. Those that are available, suffer from a number of problems: (a) many studies are qualitative in nature and their data do not go beyond the subjective views of those involved in the small-scale studies; (b) some studies are informal and did not use a methodologically robust single-subject or group research design; (c) the social validity and acceptability of the assistive technologies have not been fully explored in many studies; (e) the level of obtrusiveness of the assistive technologies as perceived by the users or their significant others has not been explored at all; (f) given that most studies are very short-term, how the gains reported in these studies stack up in the longer-term, concomitant with progressive loss of cognitive capacity of the individuals, is unknown and remains a future research question.

There is intense activity in the field of Information and Communication Technology to develop integrated digital prosthetic systems that will enhance the quality of life of individuals with cognitive impairments, including Alzheimer's dementia. For example, Meiland et al. (2010) have developed a new digital multifunctional device, the COGKNOW Day Navigator, for supporting people with mild dementia in their daily lives, including memory, social contacts, daily activities, and safety. Although effectiveness of the system has yet to be fully researched, people with dementia and their support staff have reported that the system is not only useful, but also user-friendly (Meiland et al. 2012).

Wireless technologies can be used to monitor an individual's well-being and safety in supported living situations, thus enabling increased independence. For example, the Automated Technology for Elder Assessment Safety in the Environment (AT EASE) uses the ZigBee wireless communication protocol as a sensor-monitoring program (Mahoney and Tarlow 2006). This system uses motion sensors and sensors on household hardware, such as faucets and toilets. Depending on the type of alert triggered, information can be sent directly to family members, support staff or building maintenance staff. This kind of wireless system could be very helpful to families with a member who is in the early stages of Alzheimer's dementia.

Smart phone-based prompting systems offer a unique form of assistive technology to individuals in the early stages of Alzheimer's disease who are comfortable using cell phones (Donnelly et al. 2008). Interactive systems are being developed that enable family members or support staff to prerecord video messages that can be delivered at scheduled times via the phone. The messages can be linked to the individual's daily schedule, such as "time to get out of bed," "breakfast time," "time to take your medications," and so on. Current designs include a stationary camera-linked device that can be used to record and upload messages, a mobile device for the caregiver, another for the individual, and a backup storage device. This kind of assistive technology can be particularly useful for monitoring critical health needs, such as medication management, especially if the smart phones can be adjusted to have a dedicated response key that the individuals can press to say something like, "OK" or "Got it" to indicate that they received the message, and another key that says "Done" to indicate the task was completed. Further, to assess fidelity of the individual's response, programming a live video on the smart phone will enable the individual to record his response (e.g., taking medication) and automatically route it to the caregiver.

Assistive technology systems have the potential to promote and extend independent living as well as enhance the quality of life of individuals at different stages of Alzheimer's disease. One challenge has been the translation of research findings into everyday use of the technology in the context of the individual's life. For example, most research studies limit the treatment or training sessions to very short periods and report the data as if the same outcomes would be evident in the daily life of the individual. This is an assumption that is rarely tested. Current assistive technologies are being developed and evaluated with small numbers of participants, thus limiting generalizability to a wider group of people who may need the device. The challenge is to develop technologies that may be generally useful to people at specific stages of the disease. While the field is in its early stages of development, there is continuing need for further, methodologically sound research that will inform acceptance, adoption, and ongoing development of assistive technologies for people with Alzheimer's disease.

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Chapter 9
Assistive Technology for Individuals with Learning Disabilities

Diane Pedrotty Bryant, Brian R. Bryant and Min Wook Ok

Introduction

Over 20 years ago, International Business Machines (1991, p. 2) designed an assistive technology (AT) training presentation that included the statements, “For people without disabilities, technology makes things easier. For people with disabilities, technology makes things possible.” In the years since the training program was developed, AT devices and services have increased exponentially the possibilities for individuals with disabilities, including individuals with learning disabilities (LD). It is with this in mind that devices such as a calculator and instructional software can be viewed as “assistive technology” if they help individuals with LD circumvent disability-related challenges (e.g., remembering answers to math basic facts) and gain access to information and the curriculum that might otherwise be inaccessible. In fact, access to the general education curriculum for school-age students is one of the hallmark characteristics of the Individuals with Disabilities Education Act (2004); AT can play a role in promoting access, which then shifts the focus from access to learning and academic success.

In this chapter, we examine how individuals with LD use AT devices to help compensate for their disability-related academic challenges, especially, challenges in reading, writing, and mathematics. We (a) examine the nature of LD; (b) present a framework for making adaptations including AT devices in the classroom; (c) provide information about AT assessment and LD; (d) provide an overview of computer-assisted instruction (CAI); and (d) present findings from research studies on the use of AT to promote success in reading, writing, and mathematics for students with LD.

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Nature of Learning Disabilities

About 6 % of school-age children and about half of students with disabilities have a LD; thus, LD is the largest special education category in terms of number of students (U.S. Department of Education 2002). In this section, we discuss the nature of LD. We present the definitional elements of LD, which have been shared by the most popular definitions put forth over the years. We also discuss evidence-based characteristic behaviors of LD, which were revealed through an extensive review of the literature and clinically validated by classroom teachers.

Definitional elements of LD. Since the term LD was coined by Betts (1936) and popularized by Kirk (1963), people have debated how LD should be defined. However, Hammill (1990) debunked the naysayers who have suggested that the field cannot reach definitional consensus when he pointed out that the main definitions of LD (i.e., National Advisory Committee of Handicapped Children, U.S. Office of Education, Interagency Committee on Learning Disability, National Joint Committee on Learning Disabilities, Individuals with Disabilities Education Act Amendments of 1997) agree on most definitional elements. As seen in Table 9.1, most LD definitions include reference to the heterogeneous nature of LD, the notion of underachievement, a process clause, the idea that LD spans across all ages, an exclusion clause, spoken language disorders, academic disorders, and thinking disorders. With this in mind, we examine the characteristic behaviors of LD in three academic areas.

Characteristic behaviors of LD. To begin, Hammill and Bryant (1996) designed a survey to identify characteristic behaviors of individuals with LD in the six areas (i.e., reading, writing, mathematics, listening, speaking, reasoning) identified by the National Joint Committee on Learning Disabilities (NJCLD, 1981). An extensive review of the literature was conducted in the six areas; however, we focus on the survey findings that are relevant to this chapter: reading, writing, and mathematics. Results from a review of research articles, textbooks, diagnostic tests, and rating inventories, and theoretical pieces from the fields of LD and neuropsychology revealed 28 reading characteristics, 22 writing characteristics, and 31 mathematics characteristic behaviors of LD. Based on these findings, the survey was developed and sent to 36 experts who were asked to identify the degree (minimal, somewhat, or considerable) to which each of the items on the survey was indicative of a LD in reading, writing, and mathematics. The experts included officers in professional organizations related to LD, LD researchers, family members of individuals with LD, and those individuals who had LD and who were nationally recognized advocates for individuals with LD.

After receiving input from these experts, the survey was sent to 15,000 randomly selected teachers, clinicians, and therapists who worked primarily with students having LD. A total of 522 professionals from 44 states and the District of Columbia provided ratings for 2,152 students on the frequency with which their students (in Grades 2 through 12) exhibited the listed characteristics. Table 9.2 provides a representative list of characteristics in each area (for complete

Table 9.1 Status of definitional elements for learning disabilities

Definitional elements									
Definition	Hetero-geneity	Underachievement	CNS dysfunction	Process clause	Life span	Exclusion clause	Spoken language disorders	Academic disorder	Thinking disorders
Kirk (1962)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
NACHC (1968)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
USOE (1977)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
ICLD (1987)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NJCLD (1981/1994)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IDEA (1997)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

NACHC National Advisory Committee of Handicapped Children; *USOE* U.S. Office of Education; *ICLD* Interagency Committee on Learning Disabilities; *NJCLD* National Joint Committee on Learning Disabilities; *IDEA* Individuals with Disabilities Education Act Amendments of 1997

Reprinted with permission: Hammill and Bryant (1998)

Table 9.2 Characteristic behaviors indicative of specific learning disabilities in reading, writing, and mathematics

Reading	Writing	Mathematics
The individual:	The individual:	The individual:
Makes sound-letter association errors when reading aloud	Writes awkwardly	Does not recognize operator signs (e.g., +, –)
Has poor memory for letters and words	Writes slowly	Fails to read accurately the correct value of multidigit numbers because of their order and spacing
Is a slow oral reader	Misspells words by attempting to spell phonetically	Fails to carry (i.e., regroup) numbers when appropriate
Has comprehension skills that are better than attack skills	Omits words in sentences	Omits digits on left or right side of a number
Reads orally with flat, disjointed, or nonmelodic (dysrhythmic) intonation	Omits endings in words	Starts the calculation from the wrong place
Does not remember letter sequences in printed syllables	Spells poorly	Makes “borrowing” (i.e., regrouping) errors
Interchanges little words, especially articles (/a/ for *the*) when reading orally	Uses unconventional pencil grip	Skips rows or columns when calculating (i.e., loses his or her place)
Omits words when reading aloud	Confuses vowels in spelling	Reaches “unreasonable” answers
Cannot sound out words	Spells words with the correct letters but in the wrong sequence (e.g., *htnig* for *thing*)	Does not remember number words or digits
Confuses words that appear similar (e.g., *bread* for *broad*)	Repeats letters in words	Writes numbers illegibly
Omits inflectional endings (i.e., -s, -ed, -ing) when reading aloud	Forms letters correctly, but tends to slant the line upwards across the page	Misspells number words (writes 13 as *threeteen*, 20 as *twoty*)
Adds words when reading aloud	Writes wordy but content-empty passages	Cannot recall number facts automatically (i.e., unable to perform simple calculations)
Cannot break a word into syllables	Writes the wrong words (e.g., Writes *hotel* for *house*)	Counts on fingers
Cannot combine syllables into words	Writes sentence fragments	Does not follow spatial commands or directions (e.g., “place the triangle above the cross”)
Reverses sounds when reading aloud (e.g., pan as/pna/)		Jumps impulsively into arithmetic operations
Reads as thought each word is encountered for the first time		Fails to verify answers and settles for first answer

information on the mathematics characteristics (see Bryant et al. 2000; for additional information on the reading characteristics, see Bryant et al. 2004).

As can be seen in Table 9.2, challenges faced by students with LD are varied and multiple in reading, writing, and mathematics. Not all students with LD have disabilities in all three areas, but a high percentage of students have multiple LD. This poses significant challenges for teachers, who are responsible for either remediating the weaknesses or trying to find ways to help students compensate for them. Most remedial attempts are made in the elementary grades. By the time students with LD reach middle school, reading, writing, and mathematics weaknesses are deeply ingrained and pose significant detriments to meeting the demands of the general education curriculum and being adequately prepared for high stakes state assessments.

Educators face increasing accountability and feel the pressure to increase the academic performance of all students, including those with LD, in preparation for high school graduation (Achieve 2011). As a mandate of No Child Left Behind (NCLB) Act (2001), schools must apply high academic standards and are required to meet annual performance goals for all students, including those with LD (Flower et al. 2013). As never before, teachers are expected to provide high quality instruction so that all students meet high performance standards. For students with LD, AT devices can promote access (e.g., to print), and along with other evidence-based practices, potentially facilitate academic success.

Adaptations and Assistive Technology for Promoting Access and Academic Success

Adaptations are changes that are made to the instructional delivery, instructional materials, and instructional content to ensure that students with LD can access the general education curriculum (Bryant et al. 2008). The Adaptations Framework (Bryant and Bryant 1998) was developed as an approach for teachers and AT specialists to consider the setting-specific demands and related students' weaknesses and strengths to make appropriate adaptations, including the use of AT devices. Although there are many types of adaptations that can be made, such as allowing extra time for taking an exam or providing small group as opposed to whole group instruction, in this chapter, our focus is on how AT devices can be used to circumvent disability-related difficulties and promote access to the general education curriculum. Thus, how students with LD access information and print (e.g., text-to-speech software) and how they convey their knowledge and ask questions (e.g., in a spoken or written form) can be differentiated according to their needs and environmental settings.

We use the example of a sixth grade student with a reading learning disability who is taking a science class in an inclusion setting to demonstrate how the Adaptations Framework can be applied to identify appropriate AT devices to help

Table 9.3 Application of the adaptations framework for a sixth grade student in a science class

Setting-specific demands		Student-specific characteristics		Proposed
Task	Requisite abilities	Strengths	Weaknesses	AT adaptations
Students will read information about global warming on the Internet and in their science textbook	Accessing print	Has normal Visual acuity	Reading	OCR and screen reader software to access print
	Locating and reading articles from the Internet	Is able to conduct searches for class material using the Internet	Recording quickly notes for the reading strategies	Speech-to-text technology to record information for the 3 strategies
	Reading the science textbook			
	Comprehend the information from the print sources	Has learned 3 strategies, predicting, finding the main idea, summarizing, to facilitate comprehension		

OCR Optical character recognition

the student. Table 9.3 provides an example of how the Adaptations Framework can be operationalized for this student. As you read the content in this section, keep this student in mind. To begin, we have to think about the task, requisite abilities related to the task, the student, and the adaptations, which may help the student complete the task. By carefully completing each step of the Adaptations Framework, teachers can create a good match between the student's needs and AT to complete the task at hand. First, we describe each component of the Adaptations Framework and then apply those components to our student example.

Setting-specific demands. Students, especially as they grow older, encounter multiple settings as they go about their school day. It is well documented that educators must examine the demands of educational settings, which students encounter on a daily basis (Bryant and Bryant 1998; Rieth and Evertson 1988; Schumaker and Deshler 1984). The setting-specific demands are the first component of the Adaptations Framework and consist of the tasks and requisite abilities needed to accomplish these tasks. For instance, in the middle or high school setting, the teacher expects students to come to class on time, listen to instructions, take notes, read text, and write a report; i.e., the tasks of the educational setting. To perform these tasks, students must have the requisite abilities of being able to tell time; possessing the ability to hear; understanding the critical features of the lecture for note taking purposes; being able to decode and comprehend text; and knowing how to identify, organize, and produce ideas in written form, respectively. For example, we know that for many students with LD, these middle or high school setting-specific demands present challenges in terms of accessing and conveying information that must be addressed. Thus, an individual's learning characteristics must be considered.

Student-specific characteristics. Once the setting-specific demands are examined, student-specific characteristics are the next component of the Adaptations Framework for examination. Here, the requisite abilities for the settings are examined with regard to students' strengths and weaknesses. Related to LD, characteristic strengths and weaknesses typically are associated with cognitive (e.g., reading, writing, mathematics, reasoning) and language (e.g., listening, speaking) capabilities for the setting-specific demands. Students with LD may possess strengths and weaknesses in one or more areas, such as good mathematics and reasoning capabilities or reading learning disabilities, respectively. Determining a student's strengths and weaknesses in relation to setting-specific demands is important for selecting appropriate AT devices. For instance, a student who has a reading learning disability but has good listening skills may benefit from books on CD to access the reading text for class. Access to print is an important first step; the use of strategies to promote comprehension success is critical for students with LD. In another example, a student who has a mathematics LD may benefit from a computer-based program that provides visual representations to depict mathematical concepts, which are requisite abilities for grade level instruction and success. AT devices could be employed as an adaptation to facilitate access to the curriculum.

Adaptations using AT devices. Adaptations occur along a continuum from simple to complex. Not all adaptations involve AT devices (called no tech), and even AT devices range from "low tech" to "high tech." Adaptations become "assistive technology" when they help individuals improve functional capabilities or strengths—one of the elements of the Individuals with Disabilities Education Act (2004) definition of AT devices. Thus, if a student with a LD uses a device, such as a calculator, the device becomes assistive when it is "used to increase, maintain or improve the functional capabilities of individuals with disabilities." We offer examples and descriptions of AT devices and software in Table 9.4 as possibilities for students with LD with difficulties in reading, writing, and mathematics.

Let's now consider the sixth grade student with a reading learning disability who is taking a science class in an inclusion setting. This student may or may not have support from a special education teacher for a portion of the class period. The student may also use AT devices, or adaptations, for the content area classes per the Individualized Education Program (IEP). In our example (see Table 9.3), we began by examining the setting-specific demands. The students have been given the assignment of reading material about global warming (the tasks) on the

Table 9.4 Examples and descriptions of AT devices for reading, writing, and mathematics learning disabilities

Speech synthesis/Screen reading
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, and reports. These systems will read essentially any text on a computer screen. Some systems can read electronic text on the Internet
Optical character recognition (OCR)/Speech synthesis systems
An OCR system might be thought of as a "reading machine." Optical character recognition systems provide a means of directly inputting text/printed material (e.g., a page in a book, a letter) into a computer. Using a full-page flatbed scanner, text is entered in which a page of text is placed facedown on the device (much like for a copy machine), or a handheld scanner, which the student moves across a page of text (or down, depending on the particular system), or a full-page scanner. "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 student by means of a speech synthesis/screen reading system. This technology may be particularly helpful to individuals with reading disorders who exhibit no difficulty comprehending spoken language yet have problems understanding language in the written form
Word processing
Unlike the conventional methods of writing with pencil and paper or typewriter, word processors have long allowed students with LD to write without having to be overly concerned about making errors, as text can be easily corrected on-screen prior to printing. When not preoccupied with the mechanical aspects of writing, students with writing learning disabilities have a greater opportunity to focus on conveying 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 imply generate language and correct errors later may reduce writers' anxiety, liberate their writing abilities, and ultimately facilitate written expression at a level commensurate with that of their spoken abilities. Furthermore, word processing may lead to neater and cleaner documents, which may in turn help foster in writers a image of themselves as writers
Spell checking
The uses of spell checkers (generally included in word processing programs) can help compensate for writers' spelling problems, as such programs permit the student 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 student 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 student selects the correct word, and the computer automatically corrects the misspelled word in the text. Some spell checkers alert the student to spelling errors while typing (which may be disruptive to some students), whereas others check for mistakes after the document has been completed
Proofreading programs
These software programs (now included in many word processors) scan word processing documents and alert students 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 student to study the language rules checked by the program

(continued)

Table 9.4 (continued)

Outlining/Graphic organizers
Outlining programs (now included in most standard word processing programs) can help with organizational difficulties because they enable the student to "dump" information in an unstructured manner information that can subsequently be placed in appropriate categories and orders. Although each program has it own features, generally, the student 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 student 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 subordinate heading
Abbreviation expanders
Abbreviation expansion is used in conjunction with word processing and allows students 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. For example, a student with writing problems who has to frequently type out "industrial revolution" in completing written assignments for a history class might create the abbreviation "ire." To expand an abbreviation, the student simply types in the abbreviation and presses the space bar on the keyboard (or, depending on the particular program, points and clicks the mouse), 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
Speech recognition
Speech recognition systems operate in conjunction with personal computers and mobile devices. In speech recognition systems, the student operates the device by speaking to it. This may be particularly helpful for individuals with writing learning disabilities whose oral language ability exceeds their written language ability. Used in conjunction with word processors, speech recognition systems allow the student to dictate (via a microphone) to the computer-converting oral language to written text. These systems automatically learn the phonetic characteristics of a student's voice while that student dictates to the system. The more the system is used, the better able it is to understand what the student is saying
Speech synthesis/Screen
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 student 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 that are specifically designed for individuals with learning problems and that simultaneously visually highlight words as they are spoken are now available (e.g., ereader™, Read&Write™). 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 and allow for the sophisticated student to engage in what might be considered speed-reading

(continued)

Table 9.4 (continued)

Word prediction
Word prediction software supports word processing programs by "predicting" the word a student is or will be entering into the computer. Predictions are based on syntax and spelling, as well as frequency, redundancy, and regency factors. Some programs also "learn" the student'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 student can then choose the word (by pressing a corresponding number, or pointing and clicking the mouse) and the desired word will automatically be inserted into the sentence. If the desired word is not displayed, the student enters the second letter of the word and a new list appears with words beginning with those two letters
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 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 visually displayed. Furthermore, 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
Electronic math worksheets
Electronic math worksheets can help students organize, align, and navigate basic math problems on a computer screen. Addition, subtraction, multiplication, and division problems are entered via keyboard or mouse and are automatically aligned to the correct vertical format. Numbers on the screen can be read aloud via a speech synthesizer. These software programs may be helpful for individuals who have difficulty organizing and aligning math problems with pencil and paper

Reprinted with permission, Raskind and Bryant (2002)

Internet and in their science textbook. In thinking about the requisite abilities, one can identify accessing print, conducting searches, comprehending reading materials, and recording information for reading strategies as important for the task at hand. Given these setting-specific demands, the student-specific characteristics are identified and then AT devices, or adaptations, are proposed. Using Optical Character Recognition (OCR) software, the reading material can be scanned to digitally encode text and then read by screen reader software (text to speech) on a laptop or mobile device (e.g., tablet). The student now has access to the text, which was probably at a reading level that was too difficult for the student. The student can use speech-to-text software to convey information for each of the three reading strategies, predicting what the text will be about, finding the main idea, and summarizing key ideas; all of which, can facilitate reading comprehension. Thus, we can operationalize the Adaptations Framework to identify possible AT devices for students with LD.

One final note regarding the Adaptations Framework, we encourage educators to develop an *adaptations mindset*, wherein the elements of the Adaptations

Framework are considered as the teacher plans lessons. Once the tasks for the week are identified, we ask teachers to think about the requisite skills that are required to perform the expected tasks. Teachers can think about who might struggle, based on LD-related weaknesses, and what can be done to make the lessons accessible to all students. Also, AT specialists can assess student needs for assistive technology to identify AT devices for facilitating student learning and school psychologists can contribute to the student-technology match.

Assistive Technology Assessments for LD

AT assessments should incorporate a multidimensional assessment model that recognizes the dynamic interplay of various factors across contexts and over time (Raskind and Bryant 2002). Bryant and Bryant (2011) suggested that selecting AT devices requires careful analysis of the relationship among (a) the student's specific strengths, weaknesses, prior experiences, knowledge, and interests; (b) specific tasks to be performed (in this case, compensating for a reading, writing, or mathematics disability); (c) specific contexts of interaction (across classroom settings–for example, science, social studies, history); and (d) specific device qualities (e.g., reliability, operational ease, technical support, cost).

According to federal law (Individuals with Disabilities Education Act of 2004), AT assessments should be conducted in the individual's functional environment, as part of the AT service provision. For example, in a secondary setting, when the student takes classes in several classrooms, as most secondary school students do, this means evaluating the device's effectiveness in each classroom. Raskind and Bryant (2002), in their *Functional Evaluation for Assistive Technology* (FEAT), provided a means for collecting data on specific tasks that occur in a variety of settings. The FEAT scale includes forms for identifying the most appropriate and potentially effective AT device considering four major components: the individual, tasks, context, and device. By having each teacher complete the scale, the AT specialist can identify tasks and expectations in the various contexts or settings and determine the student's strengths and weaknesses. Collectively, this information is analyzed in relation to the features of various AT devices to determine potentially a good student-technology match.

A key feature of any AT evaluation is determining which device is best suited to the individual. AT vendors are helpful resources for determining the dependability of the devices they have, but users and their family members can also be valuable sources of information. There are a number of list serves (e.g., Quality Indicators of Assistive Technology–QIAT) that function as information disseminators about the quality of AT devices. It is critical to examine a device's reliability, efficacy of purpose, compatibility, screen presentation, operational ease, and technical support. In our earlier student example, the OCR and screen reader software along with the speech-to-text software were identified to compensate for the reading learning disability and to help the student access print. As part of the AT evaluation process, the AT specialist with the classroom teacher must monitor the student's progress in the classroom. Answers to questions such as "Is the device having the intended effect?" and "Is the student able to access the general education curriculum and do so successfully?" are important factors to consider as part of the AT evaluation process.

Next, we address computer-assisted instruction (CAI) as one means for promoting access to instruction and academic success. CAI has long been a mechanism for instruction in classrooms including instruction for students with LD. The effects of CAI have been studied for various academic areas that are most challenging for students with LD including reading, writing, and mathematics.

Computer-Assisted Instruction and Academic Instruction for Students with LD

In this section of the chapter, we present an overview of computer-assisted instruction (CAI) and the application of this technology to academic instruction for students with LD. CAI has been demonstrated to be an effective means of teaching whether used in isolation or as a supplemental tool combined with traditional teacher-directed instruction (Okolo et al. 1993; Ulman 2005). Researchers (Boone and Higgins 2007; Hughes and Maccini 1996; Okolo et al. 1993; Woodward and Rieth 1997) have identified instructional design variables that should be carefully considered when using CAI for teaching students with LD. The instructional variables include: (a) providing feedback and error correction opportunities; (b) ensuring multiple practice/examples and appropriate review opportunities (e.g., prerequisite skills, cumulative review, technology training); (c) including empirically-validated instructional strategies or principles (e.g., explicit, systematic instruction); (d) providing systematic curriculum organized with logically sequenced skills; (e) allowing for adjustable individual preferences (e.g., pace, level, time, goal); (f) recording student's data and providing progress monitoring; (g) enhancing motivation, and; (h) providing contents in multiple formats (e.g., text, graphics, spoken words). Interestingly, the majority of the instructional variables recommended for CAI are similar to the principles of explicit, systematic instructional design recommended as effective for teaching students with disabilities (Archer and Hughes 2010).

As CAI has evolved, programs have been used over the years as AT to enhance the reading, writing, and mathematics capabilities of students with LD (Bryant and Bryant 2011). Research has found that CAI can help students with LD enhance their skills in reading (Higgins and Raskind 2005; Higgins et al.1996; Raskind and Higgins 1999), writing (Bahr et al. 1996; MacArthur 1998; Zhang 2000), and mathematics (Chiang 1986; McDermott and Watkins 1983; Wilson et al. 1996). Additionally, CAI has been demonstrated to increase students' motivation

(Okolo 1992), time on task (Okolo et al. 1993), and independence (Manset-Williamson et al. 2008).

As technology has become more sophisticated, a new type of CAI, using mobile devices rather than desktops or laptops to deliver instruction, has emerged (Douglas et al. 2012). The mobile devices, small and handheld computing devices (e.g., smartphones iPads), gained in popularity in the late 2000s. The devices typically have a touch screen display and allow for Internet access features. Nirvi (2011) was one of the first researchers to demonstrate that mobile devices could be useful tools for students with disabilities due to the following reasons: (a) the availability of downloadable inexpensive apps; (b) the touch screen feature that allows students with disabilities to use the device without having to operate a mouse or a touchpad; (c) instant turn on/off ability; and (d) Internet access and built-in video, a camera, and audio capture hardware features. Even though there is a dearth of empirical research on the effect of mobile CAI, use of mobile devices in schools has surprisingly increased in a short amount of time (Nirvi 2011). Thus, more research is needed to determine the efficacy of mobile devices in remediating academic difficulties. In the meantime, we depend on studies that focus on the use of CAI and other AT devices, or adaptations, to promote access to instruction and academic success.

Assistive Technology used to Assist Students with Reading, Writing, and Mathematics LD

In this section of the chapter, we provide a selective overview of intervention studies that used AT, including CAI, to address academic difficulties in reading, writing, and mathematics. As part of the criteria for our selective overview, we sought empirical studies, which examined the effects of the use of AT on the academic performance of students with LD that were published within the last decade although we certainly acknowledge the earlier body of literature of our colleagues as also offering contributions to the field. We chose the last decade as a timeframe because we wanted to identify different types of AT, which were the most innovative and available for schools during this period. Also, we selected studies being mindful of the criteria for quality studies from Gersten and Edyburn (2007) as much as possible recognizing that our timeframe included years prior to the publication of this paper. Thus, we used the following criteria for identification purposes (Gersten and Edyburn 2007): (a) students with LD constituted the sample or if other students were involved, the data were disaggregated for students with LD; (b) a type (e.g., software, hardware) of AT served as the independent variable; (c) the academic areas of reading, writing, and mathematics served as the dependent variable; (d) the students were school aged (i.e., K-12); (e) the research design was single case, experimental, or quasi-experimental (i.e., we did not select studies with no comparison condition); and (f) appropriate measures (i.e., technically adequate) were used to determine the effects of the intervention. We begin with the area of reading.

Assistive technology to address reading difficulties. Reading is essential for success in school and throughout life's experiences (National Reading Panel 2000; Snow et al. 1998). As students progress through the grades, an increased amount of information is presented through text, so the ability to read and understand text is a critical skill in all aspects of society (Bryant et al. 1999; Roberts et al. 2008).

Reading refers to the process of decoding and comprehending connected text (Bryant et al. 2008). Decoding refers to translating graphic symbols into words that are in a student's listening vocabulary; reading comprehension relates to understanding the meaning of words and ideas in print (Hoover and Gough 1990). In the primary grades, instruction focuses on teaching students how to read; in the upper elementary level and in advanced grades, the focus shifts to students using their reading abilities (i.e., decoding, comprehension, vocabulary) to read and understand content area texts, such as social studies and history, science, and literature. For students with LD, who do not necessarily develop reading proficiency in the primary grades, as they advance in the grades, content area reading becomes challenging because of the increasing curricular demands of accessing and comprehending more advanced text and vocabulary (Edmonds et al. 2009; Roberts et al. 2008). For students with LD who continue to struggle with reading text, assistive technologies, including CAI, are possible beneficial solutions for accessing and learning from print in the upper grades particularly for content area instruction.

An example of using CAI to promote access to print in content area material is found in Twyman and Tindal's (2006) study on social studies instruction. Twyman et al. examined the effects of a conceptually organized, web-based intervention for teaching critical ideas, concepts, and vocabulary related to the Industrial Revolution presented in expository (i.e., informational) text. Twenty-four (experimental group: $n = 12$; control group: $n = 12$) students who were school identified as having LD participated in two 11 and 12 grade special education classes. Students were randomly assigned to the condition, experimental, or control. Most of the students (80 % experimental; 67 % control) were male and White, and 83 % of the students in each group had reading and writing IEPs. The experimental condition consisted of students using a conceptually organized, web-based text to learn and problem solve about the Industrial Revolution. Students could choose from various options to learn more about topics (i.e., big business, workers, and farmers) pertaining to the impact of the Industrial Revolution on American Society. Instructional options included an overview of the chapter with information about pertinent aspects such as important highlighted vocabulary, dates, and key information. Concepts and attributes of concepts were shown in a table as well as displayed in a graphic organizer. Text was written at an easier reading level with information about the attributes. Also, problem-solving questions were included about the text. Students in the control group received "standard instruction" where the instruction occurred from the district's textbook on the Industrial Revolution.

The study took place in the students' social studies class for 40–50 min per day over the course of approximately 2 weeks. Two curriculum-based measures were used to determine the effects of the conceptually organized, web-based text on comprehension, and an extended-response essay was employed to test problem-solving ability. Results showed that although there were no statistically significant interaction effects between groups for comprehension, vocabulary, or problem solving, which may have been a function of low power due to a small sample size, there were statistically significant differences for time. Additionally, an effect size of 0.73 (Cohen's *d*) for vocabulary, 0.67 for comprehension, and 0.84 for problem-solving indicated educationally significant findings for the concept-organized approach for learning domain specific (i.e., social studies) vocabulary, comprehending expository text, and problem-solving issues related to the Industrial Revolution. Fidelity of implementation results showed that the students in the experimental and control groups received similar amounts of questioning and practice opportunities. Also, the researchers learned after the intervention that the teacher's had a positive perspective about the conceptually framed computer-adapted text noting more student engagement and participation compared to students in the control condition who continued to have problems learning the content. Twyman and Tindal (2006) noted the potential of teaching social studies content to secondary level students with reading and writing disabilities using an interactive conceptually organized, web-based approach. They indicated that this approach could potentially help students discern important facts, concepts, and vocabulary, which are embedded in expository text structures (i.e., cause-effect, compare-contrast, problem–solution) and often difficult to discern.

In another content area study using CAI, Kim et al. (2006) examined the effects of the Computer-Assisted Collaborative Strategic Reading (CACSR; Kim 2002) program on the reading comprehension performance of middle school students with reading difficulties. CACSR is a computerized version of Collaborative Strategic Reading (CSR), which was developed to help students with reading difficulties improve their comprehension of text using strategies before, during, and after reading (Klingner et al. 1998). CSR engages students in collaborative learning groups to read text using several key comprehension strategies (i.e., previewing, activating background knowledge, predicting, finding the main idea ["get the gist,"], and summarizing) and "fix up" strategies for figuring out the meaning of unknown (i.e., "clunks") vocabulary words.

Along with important comprehension strategies, CACSR employed effective features from CAI including individually paced, interactive learning; error correction; and performance monitoring. In an urban, middle school setting, two sections of reading and language arts classes for two teachers were randomly assigned to either experimental or control condition. A total of sixteen (13 students with reading learning disabilities and 3 students with reading difficulties) students participated in the experimental condition and 18 (15 with reading learning disabilities and 3 students with reading difficulties) students participated in the control condition receiving either typical reading or language arts instruction. In the experimental group, 12 students were male; 4 students were African American, 7 were Hispanic, and 5 were European American; there were 2 sixth grade, 7 seventh grade, and 7 eighth graders. In the control condition, 9 students were female; 3 were African American, 5 were Hispanic, and 10 were European American; 3 sixth grade, 9 seventh grade, and 6 eighth students participated. In both conditions, there was an equal number of students who were eligible for free or reduced-price meals. All students were school identified as having a LD, and scored on the *Woodcock Reading Mastery Test-Revised* (*WRMT-R*) at a 2.5 grade level in decoding and at least one level below their grade in reading comprehension on the *WRMT-R Passage Comprehension* (PC) or *Gates-MacGinitie Reading Tests.* The procedures included three phases: overviewing the CACSR program, teaching CSR, and using CSR to read. In the overview, the researcher provided an explanation of the strategies and allowed time for students to practice each step. In the next five sessions, playing the role of the teacher, the computer program modeled the strategies for students and provided activities during guided practice. In independent practice, students completed activities and then received feedback on their individual performance. Finally, in sessions 11–17, students used the CACSR program to read text at their instructional level, complete a learning log about the text (i.e., "clunks" and gist statements), and receive assistance from a dictionary or "clunk" expert to decode and define unknown words. The CACSR program occurred for 10–12 weeks, twice a week, with 50 min sessions. Overall, results showed on the researcher-developed proximal measure (i.e., generating questions and finding the main idea), statistically significant differences favoring the experimental condition and on the *WRMT PC* (i.e., the distal measure). Standardized mean differences (SMD) were employed to determine effect sizes (ESs), which reflected the practical benefit of the program. On the proximal measure a SMD = 0.50–1.18 showed a positive, moderate (Cohen 1988) effect for the CACSR program and a positive, large effect (SMD = 0.87–1.18) specifically on the measure that assessed students' ability to generate questions about their reading. Overall, perceptions of the teachers were positive concerning using the CACSR intervention to teach reading comprehension. Student perceptions were positive as well regarding their improved comprehension of text and interest in continuing to use the program. Thus, findings from several reading students show promising effects for students with LD. Now, we discuss the area of writing.

Assistive technology to address writing difficulties. Writing is a complex activity involving writing processes and mechanics. Writing can be divided into two levels: (a) transcription processes (i.e., mechanical errors), such as handwriting, capitalization, punctuation, and spelling; and (b) composing processes (i.e., writing processes, grammar, and vocabulary), such as planning, composing, and revising (Graham et al. 2013).

The writing process consists of five phases: (a) prewriting, (b) drafting, (c) revising, (d) editing, and (e) publishing (Bryant et al. 2008). Prewriting involves the activities writers undertake to prepare for writing, including selecting a topic, generating ideas, and planning. After selecting a topic, the writer gathers and organizes information. Drafting results in the initial writing product. During the Drafting Stage, writers concentrate on getting their thoughts down rather than creating a completed product. Next is the Revising Stage, when writers review their drafts and make changes in content, syntax (i.e., grammar), and semantics (i.e., vocabulary). In the Editing Stage, writers focus on the mechanical aspects of writing including accuracy with spelling, handwriting, punctuation, and capitalization. Finally, in the Publishing Stage, writers submit their work to various outlets such as a course or publisher.

Students with LD may demonstrate difficulties with the writing process as well as with mechanical accuracy (Graham and Perin 2007). Access to the task of writing can be hampered by not only difficulties with the writing stages but also with the mechanical aspects of writing. To facilitate the ability to focus on the writing process, students should develop accurate and quick handwriting skills and proficiency in spelling words for successful writing (MacArthur 2009). Yet, students with LD in writing typically demonstrate more spelling, capitalization, and punctuation difficulties than typical writers (MacArthur et al. 1991). Students who have yet to master writing mechanics spend undue energy on low-level skills; difficulties in spelling words, handwriting, or punctuation interfere with acquiring the higher-level writing processes (e.g., planning and revising) (MacArthur et al. 1991, 1996). For these students, AT devices offer alternative ways to deal with writing demands (MacArthur 1998).

An example of using word prediction and text-to-speech technologies to improve writing performance is illustrated in Silió and Barbetta (2010). In a multiple baseline across subjects study, they examined the effects of using word prediction and text to speech, alone or in combination, on narrative writing abilities (i.e., syntax, writing fluency, spelling accuracy, and overall organization) of six fifth-grade boys with specific LD who were English learners. Identification of the students included teacher-identified writing difficulties and the ability to type, in less than 10 min, a 75-word essay. Additionally, student writing performance on the *Woodcock Johnson III Test of Achievement* showed about 1.5–2 years below grade level on spelling, and about 1.5–4 years below grade level on writing fluency and writing samples.

The technology intervention took place in an after-school program in the computer lab of an elementary school, which was located in a large urban setting in the southeast. Students used a PC that contained Word for Microsoft Office (Word) and WordQ™ Version 2, which included word prediction and text-to-speech features in the software. Students were randomly divided into two cohorts, Cohort A and B. Two intervention phases were conducted where Cohort A received word prediction (WordQ™) in conjunction with Word then word prediction with text to speech (WordQ™) and Cohort B used text to speech (WordQ™) with Word then text to speech with word prediction (WordQ™). Prior to the intervention, students received 30 min of individualized training on the two technologies with a focus on the technology features. Students had practice opportunities and were required to show the ability to use both technologies (i.e., Word and WordQ™ in combination). For the 8 week, 5 days a week study, both groups were given 15 min to write about a personal event (narrative composition) and prompted to stop at the end of the writing time. For scoring purposes, the dependent measures included writing fluency (words per minute), syntax as measured by T-units, spelling accuracy, and overall organization based on an adapted rubric from the *Florida Comprehensive Assessment Test* (FCAT).

Although performance varied for individual students, overall average results across the intervention phases for both cohorts, showed a stronger effect for the word prediction alone or word prediction with text-to-speech conditions for both groups on the four dependent measures. The effect of the text to speech alone condition was negligible. During the maintenance phase, which was conducted at 2, 4, and 6 weeks following the end of the intervention, overall average findings showed students performing similarly to or higher than the intervention phase. Additionally, it was noted that procedures were conducted with 100 % accuracy (i.e., treatment fidelity) and inter-rater reliability on scoring the measures were 99.7, 91.3, 99.6, and 86.6 % for writing fluency, syntax, spelling accuracy, and overall organization, respectively. The authors noted that these findings show promise for the word prediction and word prediction plus text to speech with word conditions adding to the limited research base on the positive effects of assistive technology software to improve the narrative writing abilities of students with LD and who are English learners.

Recognizing that students with LD often manifest spelling difficulties in their compositions, spell checkers are often touted as a means to help reduce spelling errors. Although a little older than our other studies, we chose to include this MacArthur et al. (1996) study as part of our selective review of research because of its focus on spelling checkers, which are incorporated into word processing programs and readily accessible for students with LD. In this study, MacArthur et al. (1996) examined the effects of spelling checkers on the performance of students with severe LD. Twenty-seven students in two middle schools (Grades 6 and 7) participated in the study; 16 were males; 13 were White, 7 were African American, 6 were Hispanic, and 1 student was Asian American. All of the students attended English/reading classes for students with LD and demonstrated significant writing problems according to results on the *Thematic Maturity* subtest of the *Test of Written Language-2* (Hammill and Larsen 1988). The mean score was 5.44, $SD = 2.06$ and the subtest mean was 10 and the $SD = 3$. Mac computers with Microsoft Word 4.0, which included an integrated spelling checker, were selected for the study because students had already been using them in the classroom. A review on how to use the spelling checker was conducted over 2 days where guided and independent practice were used to ensure students could use the software correctly. Next, students wrote compositions without the aid of the spelling checker in response to a prompt for 2 days in 45 min class sessions. Students were provided with a hard copy of their compositions and were required to edit them by circling and correcting spelling, capitalization, and punctuation errors without assistance. Finally, anywhere from 4 to 8 days later, students edited their papers using the spelling checker unaided by their corrections during the their previous editing. Four assessments were used to measure spelling performance. *The Test of Written Spelling, Third Edition* (TWS-3; Hammill and Larsen 1988) was used to measure spelling performance of predictable and unpredictable words on student writing samples. *The Thematic Maturity* subtest of the *Test of Written Language-2* (TOWL-2; Hammill and Larsen 1988) was used to measure number and percentage of words misspelled and the percentage of misspelled words on the writing sample was calculated.

Data were collected on the number of words and spelling errors, words corrected using the spelling checker, and student corrections without the spelling checker. Overall results revealed average to severe spelling performance. Findings on the TWS-3 showed mean standard scores of 83.22 (*SD* = 8.7, range = 69–109) and 77.11 (*SD* = 7.6, range 63–97) on predictable and unpredictable words, respectively. On the *Thematic Maturity* subtest of the *TOWL-2*, the mean percentage of misspelled words was 16.4 % (*SD* = 49.9, range = 27–247) and on the writing sample, the mean percentage of spelling errors was 13.4 % (*SD* = 4.8–28.3 %). Interestingly, additional analyses revealed that students identified an average of 63.0 % of spelling errors and corrected 36.5 % of them; whereas, without the spelling checker, an average of 27.9 % of errors were identified and 9.3 % of these errors were corrected; the difference between performance (with and without the spelling checker) was statistically significant. Further, findings on student use of the spelling checker to correct their errors showed that, on average, 81.5 % of misspellings were corrected when the intended spelling was presented and the percentage increased to 83.5 % when the intended word was first in the list of corrections. However, when the student's spelling of a word was so poor, no suggestions by the spelling checker were offered or suggestions did not include the intended word. In these cases, only 24.7 % of the spelling errors were corrected, no change to the misspelled word was made 30 % of the time, and 48 % of the time another misspelling of the intended word was typed by the student. Therefore, the severity of the misspelling of the word influenced the degree to which the correct spelling was identified and inserted.

Thus, using the spelling checker to identify errors and corrections appeared to be beneficial for students with LD and writing difficulties particularly if the correct spelling of the word appeared first in the list of suggested spellings offerings for the misspelled word. MacArthur et al. (1996) recommended that words be added to the spelling checker dictionary to improve the availability of words commonly found in writing especially the student's writing; however, not recognizing spelling errors that are other correctly spelled words (e.g., hear, here) is a spelling checker limitation and warrants further investigation. So various types of AT software and the use of spelling checkers in this review showed promising results for students with writing disabilities. Finally, we discuss the area of mathematics.

Assistive technology to address mathematics difficulties. Mathematics is an important topic of instruction for all students. The Individuals with Disabilities Education Act (2004) indicated that mathematics learning disabilities involve difficulties in the area of calculations and/or word problem solving. Difficulties with calculations are a defining characteristic of students with mathematics LD (Gersten et al. 2005; Hanich et al. 2001; Jordan et al. 2002), and are an important contributor to students' inability to solve whole number computation and word problems (Fuchs et al. 2005).

Mazzocco and Devlin (2008) found in their longitudinal study with 147 6th, 7th, and 8th grade students with mathematics learning disabilities, mathematics difficulties, and typical achievers (TA) that students with mathematics learning disabilities performed more poorly on ranking proportions with fractions and decimals (e.g., ranking smallest to largest decimals [numerically displayed] and fractions [pictorially displayed] than the other two groups of students). Additionally, students with mathematics learning disabilities manifested significantly more difficulties in identifying fraction and decimal equivalence ($0.50 = \frac{5}{10}$) as compared to students with mathematics difficulties and students who were TA. Mazzocco and Devlin (2008) attributed poor conceptual understanding of rational numbers (i.e., weak number sense) as a possible explanation for low performance in basic tasks (i.e., equivalence of rational numbers and comparing and ordering fractions and decimals), which are associated with earlier grades content.

Undoubtedly, a significant number of children and adolescents demonstrate poor mathematics achievement (Swanson 2006) that is persistent and pervasive with potentially long-term mathematics difficulties (Geary 2004; Murphy et al. 2007).

Students with MLD should be evaluated for the possible use of AT devices to promote learning and access to the curriculum (Bryant and Bryant 2011). Clearly, given the use of technology in earlier mathematics studies, one might surmise that the application of technology should continue to be explored.

Given the rapidly increasing interest in the use of iPads and other mobile device in classrooms Nirvi (2011), Bryant et al. (2013) studied the effects of using the iPad to teach multiplication facts (x4 and x8) to fourth grade students with LD in mathematics. Three conditions were examined using an alternating treatment design; condition included teacher-directed instruction (TDI), application instruction (AI), and combined instruction (CI) consisting of teacher-directed and the iPad application. The conditions were randomly sequenced and assigned at the beginning of the study. Four boys and two girls who attended a charter school participated; two students were of mixed ethnicity and four students were Hispanic. Five of the six students had free/reduced lunch status and five of the six students' math performance on a norm-referenced assessment showed a standard score below 90; one student had a standard score (92).

Students received a 30 min intervention 5 days a week for 15 days consisting of x4 facts on sessions 1 through 6, x8 in sessions 8 through 10, and a combination of x4 and x8 facts in sessions 11 through 15. Progress was measured using daily 2 min multiplication fact alternate form probes, which was the dependent measure, consisting of 35 problems each for x4 and x8 facts.

For the AI condition, students used two math applications. The Math Drills application was used after completing a brief training on the iPad and the application. Math Drills included drill-and-practice activities and a progress-monitoring feature along with visual representation (e.g., blocks, number lines) to assist with solving the problems. The Math Evolve was more of a game-like application including a practice mode and a progress-monitoring tracking feature. Both applications allowed for programming the facts that were targeted; thus, students only practiced the designated facts (x4 or x8) for this condition. The TDI condition included an Engaged Prior Knowledge, Preview (advance organizer), Modeled Practice (i.e., the teacher teaching the skills and engaging students during the modeling), Practice 1 and 2, and an Independent Practice activity. Finally, the CI condition incorporated both AI and TDI. The Engage Prior Knowledge, Practice 2, and the 4 min Independent Practice sections of the lesson involved the Math Drills application. The Preview, Modeled Practice, and Practice 1 sections were administered using TDI. At the end of the lesson, the 2 min probe was given. Fidelity of implementation data were collected showing an average fidelity rating of 23.1 out of 24 possible points across interventionists and instructional procedures; thus, reflecting a high degree of fidelity in the implementation of the three different instructional procedures.

Results were analyzed in several ways including averaging the scores across conditions, rank ordering the scores to compare conditions, and graphing the daily scores.

Averaging of the scores showed, overall, TDI had the highest average (42 %) of student scores, followed closely by CI (40.50 %), and then AI (31.20 %). Rank ordering of average digits correct on the progress monitoring measure revealed AI with 14 digits correct per minute followed by CL (12 digits) and TDL (10 digits). Analyzing individual student scores showed that students 1, 2, 3, and 6 scored highest for TDI. Student 4 scored highest for the AI condition, and Student 5 scored highest during CI. Looking at lower performance scores showed students 4 and 5 lowest for TDI. During the AI condition, students 1, 3, and 6 scored lowest and the CI condition showed the lowest scores for student 2. In, summing the rank orders, TDI had the best set of scores, followed by CI and AI. For the graphs, visual inspection of the graphs revealed mixed interpretation of the data because of the degree of overlap, which makes it difficult to discern which condition was most effective. Overall, the data seem to suggest stronger findings for the TDI.

Finally, social validity data were collected from students and the interventionists. Generally, all three approaches received support by both the students and interventionists. Interestingly, AI received no votes from the students when they were asked which approach helped them learn the most. However, at least one student and interventionist viewed AI favorably.

In another study that used technology as part of the intervention, Seo and Bryant (2012) examined the effects of the Math Explorer program, which taught word problem-solving (WPS) skills to students with mathematics difficulties. The study focused on the effects of the CAI on math performance as measured by computer-based tests, generalization of the results on paper–pencil tests, and maintenance of math performance 3 to 6 weeks after the intervention concluded.

Four students (1 female and 3 males) in 2nd and 3rd grade participated in the study. Two students were Hispanic, 1 student was African American, and 1 student was White; all of the students qualified for free or reduced lunch. Based on the criterion of 30 % accuracy or lower on the screening test, all students qualified as having low math performance.

Math Explorer was based on a cognitive-metacognitive strategy for teaching WPS consisting of four cognitive strategies (Reading, Finding, Drawing, Computing) and three metacognitive strategies (Do, Ask, Check). The instructional design features consisted of goals, modeling, guided practice, and independent practice. Other features included reviewing prerequisite knowledge, teaching vocabulary, using visual representations, providing feedback, and a text-to-speech function.

The study occurred for 18 weeks and involved teaching the students how to use the technology and program, providing a screening test, and then initiating the intervention using a multiple-probe-across subjects design. The intervention occurred for 20–30 min with five sessions per week and a follow-up session about 2 weeks after the end of the program.

Results showed that all four students demonstrated increasing trends from 0 % at baseline for three of the four students to 16, 16, 27, and 22 % for Students 1–4, respectively, on computer-based tests. For paper–pencil tests, findings for Students 1–4 showed an increase in accuracy percentage scores from 0 to 22, 16, 22, and 22 % on the first intervention day, respectively; the intervention data showed a steep trend and exceeded the criterion level set at 70 % accuracy. Moreover, the follow-up maintenance data showed continuing high levels of accuracy (i.e., above 70 %) for the 3–6 week follow-up phase for three of the four students; the lowest score was 75 % and the highest maintenance score was 100 %.

Overall, findings from these studies demonstrate some potential benefit of AT devices to help students with LD improve their reading, writing, and mathematics performance. Interestingly, in reading Twyman and Tindal's (2006) study showed educationally significant findings; where as, findings from Kim et al. (2006) showed statistically significant differences favoring the experimental condition. There was about an 8 week difference in the amount of intervention time with the Kim et al.'s study showing longer intervention duration, which might in part account for these differences in findings. In writing, results from the two studies supported the use of AT software including word prediction, word prediction with text to speech, and spelling checkers. Interestingly, text to speech as a condition did not produce positive results with the group of students in the study. Finally, in mathematics, mixed findings were noted; findings from the 3-week study slightly favored TDI over CI and AI; perhaps with a longer duration, results could have been more definitive. In the 18-week study using CAI to teach WPS, findings were positive for all four participants whose data showed steep trend lines depicting performance growth across the study.

Summary

In this chapter, we examined how AT devices can help students with LD access and meet the demands of the general education curriculum. We did so by examining the definitional elements and characteristic behaviors of LD. We presented the Adaptations Framework, a model we designed years ago, to help teachers examine the setting-specific demands of their classrooms, that, is the tasks they expect students to accomplish and the requisite abilities required to do the tasks, and compared those to the student-specific strengths and weaknesses presented by students with LD. The Adaptations Framework can assist teachers in considering a variety of possible adaptations that can be made to help students meet the challenges posed in the classroom. We then presented descriptions of AT devices that are available for instruction to promote academic success in reading, mathematics, and writing, and discussed a process for conducting an AT assessment for students with LD.

Instructionally, we discussed how CAI has progressed over the past 30 years to be a viable option for students with LD to improve their reading, writing, and mathematics abilities. Finally, an overview of findings from research studies involving AT devices and academic areas offered insight about the potential promise of AT to promote access and academic success.

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Chapter 10
Assistive Technology for People with Severe/Profound Intellectual and Multiple Disabilities

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Introduction

Assistive technology is a general terminology that refers to multiple technological resources, which are employed with persons with different disabilities in the attempt to help them obtain behavioral and social benefits and reduce the negative impact of their conditions (Bauer et al. 2011; Brown et al. 2009; Reichle 2011; Shih 2011). The first requirement for a successful use of any form of assistive technology is that it matches the persons for whom it is employed, that is, it suits their characteristics (i.e., response conditions and abilities) and their environments (Bauer et al. 2011; Borg et al. 2011; Burne et al. 2011). A second requirement is that the technology is used as part of an explicit and carefully designed intervention program aimed at ensuring that the persons learn how to use it effectively.

In light of the above, one can argue that new developments of technological resources for persons with disabilities would need to be paralleled by effective intervention programs to enable those persons to fully benefit from such resources and increase their positive performance (Burne et al. 2011; Lancioni et al. 2012a; Rispoli et al. 2010). This link between technology and intervention programs could

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be seen as an increasingly important objective for any context dealing with persons with severe to multiple disabilities, that is, persons who (a) have serious limitations in their developmental, communication, and/or occupational perspectives and (b) need extensive support to increase their general participation opportunities (Holburn et al. 2004; Lui et al. 2012; Moisey 2007; Moisey and van de Keere 2007; Ripat and Woodgate 2011; Scherer et al. 2011; Tam et al. 2011). Pursuing such an objective amounts to integrating rehabilitation engineering with rehabilitation psychology in a general education/rehabilitation project (Borg et al. 2011; Lancioni et al. 2012a; Parette et al. 2010).

This chapter provides an overview of studies that focused on intervention programs and technological resources aimed at enhancing the performance/achievement of persons with severe and profound intellectual and multiple disabilities. The general goals of the studies were to promote adaptive behavior and environmental stimulation control (and occasionally also reduce problem posture/behavior), communication, preliminary ambulation skills, indoor orientation and travel, and task engagement. The studies were divided in four groups (with possible subgroups) based on the technological resources they assessed. The main technological resources employed were: microswitches, speech-generating devices (SGDs), spatial orientation systems, and activity instruction systems. The final part of the chapter provides general considerations about the studies (technological resources) reviewed and their implications for daily programs and also suggests several issues for new research in the area (Furniss et al. 2001; Lancioni et al. 2007a, 2008a; Lancioni and Oliva 1999; Rispoli et al. 2010; Sigafoos et al. 2009; Thunberg et al. 2007). Table 10.1 presents a summary map of the chapter concerning the four main groups (and subgroups) of studies reviewed in relation to the four technological resources mentioned above.

Table 10.1 Chapter summary map

Studies reviewed (Technological resources)
Group 1: Microswitches
Subgroup 1: Promoting simple adaptive responses and positive occupation
–Studies with a single typical response and commercial microswitch
–Studies with a single nontypical response and an experimental microswitch
–Studies with two or more responses and commercial or experimental microswitches
Subgroup 2: Promoting adaptive responses and curbing problem postures/behaviors
Subgroup 3: Promoting the performance of ambulation steps
Group 2: Speech-generating devices
Group 3: Indoor orientation systems
Subgroup 1: Orientation studies with direction cues
–Studies with auditory cues
–Studies with visual (light) cues
Subgroup 2: Orientation studies with corrective feedback
Group 4: Instruction systems for activities

Microswitches

Microswitches are a main form of assistive technology, which is instrumental to monitor one or more responses of the person involved in the program and connect these responses to environmental events thus allowing the person to control those events (Holburn et al. 2004; Lancioni et al. 2001a, b, 2004a, b, c, 2008a; Mechling 2006). For example, an optic microswitch (e.g., a photocell) placed on the person's wheelchair tray could allow the person to activate brief periods (e.g., 10 s) of preferred light stimulation with a simple hand movement activating the photocell (rather than with the more difficult or impossible manipulation of the light device) (Lancioni et al. 2001a, 2002d, 2007b, 2008a). A pressure microswitch arranged on the headrest of the person's wheelchair could allow the person to activate brief periods of vibratory stimulation or music with a simple head movement response (Lancioni et al. 2002b, 2008a). In practice, the microswitches may be viewed as tools that allow the persons to gain control over environmental stimuli even without the motor skills necessary to manipulate the sources of such stimuli (Holburn et al. 2004; Lancioni et al. 2008a; Mechling 2006). Microswitches have been mainly used for (a) promoting simple adaptive responses and positive occupational engagement with the opportunity to access preferred environmental events, (b) promoting adaptive responses and reducing problem postures/behaviors, and (c) promoting the performance of ambulation steps.

Promoting Simple Adaptive Responses and Positive Occupation

Before determining the type of microswitch that should be used with a certain person, one has to select the best possible response available to that person for a microswitch-based intervention program. In general, such response would have to be present (although at low frequencies) in the person's repertoire, reliable and relatively easy to perform so that the person does not get tired in using it. The microswitch might be available commercially or may need to be built for the specific person/purpose. The important point is that it matches the response selected successfully and can monitor it in a dependable way (Lancioni et al. 2008a, 2012a). The person would be expected to be active and respond (i.e., use the microswitch) provided that the events he or she can control through such responding are interesting/motivating. Thus, it is always essential that motivating events/stimuli are available for the person before the start of any intervention. This availability may be ensured through the use of stimulus preference screening procedures (Crawford and Schuster 1993; Lancioni et al. 2008a).

The studies using microswitches for promoting simple adaptive responses and positive occupation (i.e., the group of studies pursuing the first of the three goals mentioned above) may be divided into three subgroups based on the responses the participants used and the microswitches adopted for those responses. The subgroups would include (a) studies that targeted a single typical response (e.g., head turning) through the use of a commercial/conventional microswitch (e.g., a pressure device); (b) studies that targeted a single nontypical response (e.g., chin movements) through the use of an experimental microswitch (e.g., an optic sensor); and (c) studies that targeted two or more responses (typical and non-typical) through the use of commercial and/or experimental microswitches.

Studies with a single typical response and commercial microswitch. The most common responses used within this subgroup of studies concerned head and hand movements (Leatherby et al. 1992; Saunders et al. 2003). The microswitches generally employed to monitor those responses were simple pressure devices (Dewson and Whiteley 1987; Gutowski 1996; Holburn et al. 2004; Lancioni et al. 2002c; Leatherby et al. 1992; Mechling 2006; Realon et al. 1988; Sandler and McLain 1987; Saunders et al. 2003; Wacker et al. 1988).

For example, Wacker et al. (1988) reported a study with five participants of 13–20 years of age whose level of functioning had been estimated to be below the 1-year level. The microswitch available for four of the participants was a contact/pressure device, which was placed in front of them and could be activated with a simple hand pressure response. The microswitch available for the fifth participant was a tilt device that could be activated with an arm-lifting response. Microswitch activation allowed the participant to access one of the two toys available. Such access would last for as long as the pressure response lasted or the arm remained lifted (i.e., for as long as the microswitch remained activated). The toys were changed across sessions according to an alternating treatments design. Data showed that during the intervention condition (i.e., when responding led to toy stimulation), all participants increased the duration of their responding and also showed a preference for one of the toys over the other.

Lancioni et al. (2002c) assessed the possibility of using simple hand-tapping responses (i.e., forms of slightly forceful contact with the tabletop that did not need to focus on the same specific area of the table) together with a vibration microswitch. The participants were two girls of 7 and 14 years of age who presented with combinations of intellectual, motor, and sensory disabilities and were confined to wheelchairs. Their hand-tapping responses activated the vibration microswitch and allowed them to access brief periods of preferred stimulation such as music, lights, and vibratory input. The girls' level of hand-tapping responses was fairly low during baseline conditions and increased in a decisive manner during the intervention periods indicating that the responding was positively impacted by the stimulation that occurred contingent on it.

Holburn et al. (2004) carried out a study with five participants between 23 and 40 years of age who had a diagnosis of profound intellectual disability and extensive motor impairment requiring the use of wheelchairs. The participants did not have any functional communication system and depended on caregivers for their daily needs as well as stimulation input. The microswitches consisted of pressure devices that could be activated with hand or head movements. The stimuli that the participants received contingent on their responses consisted of visual images presented on a computer screen, which could be supplemented by sound effects. A series of 50 images were available within each session. The results indicated that response increases were substantial in two participants, moderate in a third participant, and vague/limited in the final two participants.

Mechling (2006) taught three participants to use hand/arm movements and head turning responses in combination with pressure microswitches to access various environmental stimuli. The participants were between 6 and 19 years of age and presented with profound intellectual disabilities and serious motor impairment. The study included nine sessions of 9 min. Every session contained three intervention segments of 3 min. Each segment involved a specific stimulus condition, that is, a specific type of consequence occurring contingent on the responses per 10 s at each response. The stimulus conditions involved adapted toys and devices, commercial cause and effect software, and instructor-created video programs. Subsequent to this period, which was aimed at verifying possible differences in responding under the different stimulus condition, a program extension was implemented. Such an extension consisted of three sessions, in which only the stimulus condition that had promoted the highest level of responding was used. The results of the first assessment period showed that the level of responding was highest (i.e., between five and nine responses per 3-min segment) with the instructor-created video condition. During the program extension, the response level remained satisfactory for all three participants.

Studies with a single non-typical response and an experimental microswitch. The problem with typical responses and commercial microswitches is that they may not be suitable for persons with pervasive disabilities and a minimal behavioral (motor) repertoire (Lancioni et al. 2005c, 2008a). To give these persons an opportunity to participate in microswitch-aided intervention programs, one has to select small, non-typical responses that might be more feasible for them and to resort to the use of new microswitch devices that can detect such responses. Those responses could include, among others, vocalizations (voice emissions), eyelid or chin movements, minimal hand closures or finger movements (Lancioni et al. 2001c, 2004a, c, 2005a, d, 2006c, f, 2007a, b, c, d, e, 2009a, b, c, 2010c, 2011a, 2012b, c).

For example, Lancioni et al. (2001c) conducted the first study with the *vocalization response* and assessed the possibility of using it profitably with two children of 7 and 10 years of age. Both children had pervasive multiple disabilities with minimal motor repertoires, but emitted spontaneous vocalization responses. These responses were considered a relevant resource and targeted for the study in combination with a new (specifically built) microswitch. The microswitch involved a battery-powered, sound-detecting device, which was linked to a throat microphone (not affected by environmental noise). The microphone was kept at the participants' larynx, through a simple neckband. During the baseline, the children's vocalization responses were only recorded. During the intervention, the vocalization responses led to the occurrence of brief periods of preferred stimulation. This included a variety of stimuli (differing across children and also across sessions), which were regulated through an electronic control system. Data showed that the children's levels of responding increased substantially from the baseline to the intervention period and remained largely stable through the latter period, suggesting that the children continued to remain actively engaged and positively motivated.

The aforementioned microswitch was upgraded by Lancioni et al. (2005d) and used for the *vocalization response* of a girl of 8 years of age with profound multiple disabilities. The upgrading was decided based on the fact that a contact (throat) microswitch might present with false activations if the person has heavily congested tracheal areas or makes some abrupt (dystonic) movements of head and neck. The upgrading served to reduce (virtually eliminate) the risk of false activations. To this end, the throat microphone was paired with an airborne microphone. Microswitch activation would occur only if both microphones were triggered simultaneously. This solution seemed to be effective for reducing the aforementioned risks. The girl showed low levels of vocalization responses during the baseline and fairly high levels of responding during the intervention (i.e., when responding allowed access to preferred stimulation).

Lancioni et al. (2005a) examined the possibility of using a repeated *eyelid closure response* and an optic sensor mounted on an eyeglasses' frame with a boy of 9 years of age with profound multiple disabilities and minimal motor behavior. The response, which was to include two eyelid closures (i.e., two blinks) within a 2-s interval, was already present at low frequencies in the child's repertoire. The microswitch seemed relatively simple and apparently reliable in monitoring the response. Its use served simply to record the responses during the baseline phases of the study, while it also ensured brief periods of stimulation contingent on them during the intervention phases of the study. The child's level of responding (i.e., his activity engagement) showed a definite increase during the intervention phases with consequent increase in stimulation input.

Lancioni et al. (2012c) extended the use of the *eyelid response* and of the optic microswitch with three post-coma adults in a minimally conscious state and affected by pervasive motor impairment. The response consisted specifically of repeated eyelid closures (as in the aforementioned Lancioni et al.'s 2005a study) for one of the participants and of a protracted eyelid closure (i.e., longer than 0.7 s) for the other two participants. The microswitch (i.e., optic sensor) was not mounted on an eyeglasses' frame. Rather, it was held with a thin wire structure around the participant's ear and fixed with medical tape just above the participant's cheekbone, that is, in a position that would not interfere with the participant's normal visual functioning. To ensure that the participants' eyelid closure could be effective to activate the sensor, a mini paper sticker was attached to their eyelid. The data seemed to indicate that the microswitch arrangement suited the participants' characteristics and all three of them increased the responding level during the intervention period, with the consequence that their stimulation input also increased in a very substantial manner.

In an additional research attempt with the *eyelid response*, Lancioni et al. (2011c) assessed the usability of a camera-based microswitch technology with a post-coma patient in a minimally conscious state. The patient was provided with a blue color spot on her left eyelid. The spot was minimally visible when the eyelid was open and largely visible when the eyelid was closed. Whenever an eyelid closure was recorded (i.e., whenever a large increase in the color spot was detected by the camera-based microswitch), the system enabled the patient to receive a brief stimulation. The patient showed a clear increase in responding (i.e., with a positive trend in the data) during the intervention phases of the study.

Lancioni et al. (2006c) assessed the use of *chin movements* with two children of 7.5 and 8 years of age. The children were diagnosed to be functioning in the severe or profound intellectual disability range while presenting with minimal residual vision or blindness and pervasive motor impairment. Their motor impairment prevented them from any useful interaction with their environment and any contact with objects was to be mediated by their caregivers. The specific response used for them, as it was deemed reliable to control environmental events and relatively easy (non-tiring) to perform, was downward chin movement. Two microswitches were developed for monitoring the response, one for each of the children. The first microswitch consisted of (a) a position sensor arranged inside a box which was attached to the side of a hat, (b) a regulation unit allowing one to determine the level of sensor shift necessary for recording a response, and (c) a light band, which connected the position sensor with the other side of the hat, and passed under the chin. By producing a downward movement of the chin, the child pulled the band and moved the position sensor. If the sensor's movement exceeded the preset shift value, the regulation unit recorded a response and sent a signal to an electronic control unit. During the intervention periods of the study, the responses would allow the child to access preferred stimuli for brief periods of time.

The second microswitch consisted of an optic sensor held underneath the child's chin through a light wire structure attached to the child's hat. The optic sensor was activated as soon as the chin came to a specific distance from it (i.e., as soon as a downward movement of the chin exceeding a preset extension occurred). Activation of the optic sensor during the intervention periods of the study allowed the child to access brief stimulation periods (i.e., as for the first child). The results of the studies were equally satisfactory. Both children presented relatively modest levels of responding during the baseline periods and clear increases of their responding during the intervention periods.

In an effort to upgrade the microswitch technology and improve the intervention effects, Lancioni et al. (2011a) used a camera-based microswitch for a variation of the *chin movement response* (i.e., mouth closing) of a child with multiple disabilities. The child was nearly 5.5 years old and had a diagnosis of congenital encephalopathy with multiple (intellectual, sensory, and motor) disabilities. The camera was positioned at about 1 m from the child's face. Two color dots were drawn in the child's face (i.e., one on her nose and the other under her lower lip) to allow the camera and the computer connected to it to detect the response. When the distance between the two dots showed a variation exceeding 25 % of its original value, the computer recorded a response and every response allowed the child brief access to preferred stimulation during the intervention periods. The child's response frequency was reported to increase largely as a consequence of the intervention conditions.

Lancioni et al. (2007b) assessed the possibility of using small *hand-closure movements* as the target response with two participants of 5 and 21 years of age. This response seemed highly suitable and relatively easy for persons who tend to have their hands partially closed. It consisted of the participants' fingers touching or pressing on a two-membrane microswitch fixed into the palm of their hand. The external membrane of the microswitch (i.e., the one exposed to immediate/direct contact with the participants' fingers) was a touch-sensitive sensor and thus it was activated by light contact with any of the participant's fingers. The internal membrane was a pressure sensor that would be activated only if the participant applied a pressure/weight of about 20 g on it. During the baseline phases (i.e., when responses were simply recorded), the participants' response frequency was fairly low. During the intervention phases (i.e., when responses ensured access to brief periods of preferred stimulation), the participants' response frequency showed a large increase, which remained rather consistent.

Lancioni et al. (2012b) assessed the use of small *finger movements* (i.e., any small change in the position of the fingers/hand) as the response for a post-coma woman of 53 years of age who (a) was functioning at the lower end of the minimally conscious state and (b) presented with spastic tetraparesis with tendon–muscle retraction and lack of head and trunk control. The microswitch consisted of a touch-sensitive pad, which was placed under the woman's right hand. Each square inch of the pad worked as an independent device. Any finger/hand movement affecting one of the squares/devices represented microswitch activation. Such activation triggered a microprocessor-based control system, which presented brief periods of music and songs. During part of the intervention, the periods of music and songs were combined with light body massage stimulation. The study was carried out according to an $ABABB^1CB^1$ sequence, in which A represented baseline phases, B intervention phases with the music and songs contingent on responding, B^1 intervention phases with the combination of music and songs and body massage, and C a control phase with music and massage available continuously during the sessions. The results showed that the woman had (a) an increase in responding during the B phases compared to the baseline periods and (b) a further increase in her response frequencies during the B^1 phases compared to the B phases and even more to the C (control) phase.

Studies with two or more responses and commercial or experimental microswitches. Targeting a specific response with a microswitch may be considered an essential first step to help persons with pervasive and multiple disabilities develop adaptive responding and access environmental stimulation independently (Lancioni et al. 2001d, 2008a). Many of these persons might have the ability to acquire more responses with more microswitches with obvious benefits for their activity and stimulation input, as well as in terms of choice opportunities. In those cases, the persons would use multiple responses/microswitches to access various stimuli and could privilege any response based on their possible preference for the stimuli related to such response and/or for the response per se (Lancioni et al. 2002a, 2003, 2004b, 2006b, 2009b, 2010b, e; Sullivan et al. 1995).

For example, Sullivan et al. (1995) reported an early research study aimed at targeting two responses with two separate microswitches. The participant of the study was a girl of 3.5 years of age who had a diagnosis of Rett syndrome. The two responses targeted for her use during the study consisted of head backward movements and hand pushing/stroking movements. The microswitches employed to monitor those responses were commercially available pressure devices. The microswitches were simultaneously present during the sessions and the girl could activate either one of them. Microswitch activations were to allow access to different types of preferred stimuli (e.g., musical toys and tapes) during the intervention. The results indicated that there was an increase in the girl's performance of both responses as a consequence of the intervention conditions.

Lancioni et al. (2003) assessed the possibility of using two responses and two microswitches with an adolescent with multiple (intellectual, motor, and visual) disabilities. Psychological reports described her as functioning in the profound intellectual disability range. She had no speech or other forms of communication and was fitted with a feeding tube. The two responses selected for her during the study consisted of bringing the hand to the forehead and moving the knee laterally. The microswitch used for the first response consisted of a combination of optic sensors attached to a headband that the participant wore. The microswitch used for the second response consisted of a tilt-like device. The study started with a baseline on each of the responses. This was followed by intervention on the first response. Performance of this response during the intervention led to brief periods of visual and auditory stimulation. Once this response had increased, a new baseline and intervention were carried out on the second response. The emission of the second response during the intervention also led to brief periods of stimulation (i.e., a package that differed from that used for the first response and included vibratory input as well). The results of the study were positive. The participant increased the frequency of each response as a consequence of the intervention conditions.

Lancioni et al. (2009b) assessed the use of two responses and microswitches with a man of 45 years of age who had suffered extensive brain injury and coma and presented, at the time of the study, with a minimally conscious state and extensive neuromotor disabilities. The two responses targeted for the study were head and foot movements. The microswitches employed for these responses consisted of pressure devices, which were attached at the wheelchair's headrest and of a combination of tilt and pressure devices, which were fixed on and next the man's right foot, respectively. After the initial baseline, the intervention started on the first response. The study continued with the baseline and the intervention on the second response. Eventually, both microswitches were available and the participant could perform either response, as he wanted. Throughout the intervention, the head movement response (activating the headrest's pressure devices) allowed the man to access short video clips; the foot movement response (activating the combination of tilt and pressure sensors) allowed him to listen to brief audio recordings. The man showed an increase of responding during the early intervention phases (i.e., when the intervention was focused on one response at a time) and continued to have high responding levels during the final phase of the study (i.e., when either response was possible given the simultaneously availability of the microswitches). Apparently, the man had some preference for the foot movement response.

Lancioni et al. (2010e) assessed the use of two responses with two post-coma adults (a woman and a man) of 79 and 52 years of age, who presented with a minimally conscious state and extensive neuromotor disabilities. The responses targeted for one participant were right and left head turning. The responses targeted for the other participant were right and left head bending. The microswitches used for the head turning responses were tilt devices fixed on a headband. The participant was lying in bed and wore the headband during the sessions. The microswitches used for the head bending responses were optic microswitches that the participant had on each shoulder. The responses were exposed to intervention in sequence. Eventually, the participants could perform either of them at will, as both microswitches were simultaneously available. Each response allowed the participant brief access to a specific stimulation package. The results showed that both participants increased their response frequencies during the intervention. One of the participants showed a clear preference for one of the responses (and the stimulation available for it) during the final phase of the intervention when choice was available. The other participant did not seem to have specific preferences between responses and stimulation packages.

Promoting Adaptive Responses and Curbing Problem Postures/Behaviors

Persons with extensive multiple disabilities are known to pose serious concerns because of their limited range of adaptive responses and minimal tendency to engage with their environment (Lancioni et al. 2012a). The literature on the microswitch technology reviewed above is an attempt to provide an answer to those concerns. The same people may also pose other concerns, namely, problems with inadequate postures (e.g., head forward bending) and aberrant behavior (e.g., hand mouthing and eye poking). Traditionally, intervention programs have targeted the two groups of concerns separately, with programs aimed at increasing positive responding and programs aimed at reducing inadequate postures and aberrant behavior. During the last 10 years, a new approach has been put forward that combines the use of microswitches to target both the positive/adaptive responding and the negative posture/behavior (Lancioni et al. 2007e, 2008a, e, 2009c, e).

For example, Lancioni et al. (2007e) assessed the feasibility and effectiveness of a program based on a combination of microswitches (i.e., on a microswitch cluster) for two children of about 8 and 12 years of age who were deemed to function in the profound intellectual disability range, presented with minimal residual vision or total blindness and spastic tetraparesis. The adaptive responses selected for the two participants consisted of manipulating an object and moving/knocking familiar objects, respectively. The aberrant behavior consisted of hand mouthing and object mouthing. The microswitch for the first response was a wobble device hidden inside the object to manipulate and a vibration-sensitive device that would be activated by object moving/knocking. The microswitch for the aberrant behavior was an optic sensor that was held below the child's chin or to the side of the child's face. The intervention initially focused on the adaptive response. Each occurrence of the response allowed the children to access a brief period of preferred stimulation. Once the children had increased their adaptive responding through the contingent availability of preferred stimulation, the intervention was extended to deal with the aberrant behavior as well. This new intervention condition presented two changes compared to the initial phase. First, the adaptive response would lead to the onset of preferred stimulation only if it was performed in the absence of the aberrant behavior. Second, the stimulation that followed the occurrence of the adaptive response lasted the full scheduled time only if the aberrant behavior did not occur during that time. Its occurrence during that time led to the interruption of the stimulation and the need of a new adaptive response to restart it. Data showed that both children had a large increase in their adaptive responding and also succeeded in reducing the occurrence and duration of the aberrant behavior (i.e., emphasizing their self-determination and self-management skills; McDougall et al. 2010).

Lancioni et al. (2008e) assessed the possibility of using a program based on a microswitch cluster to promote adaptive responding and reduce inadequate head posture in two children and an adolescent with multiple (i.e., intellectual, motor, and sensory) disabilities. The adaptive responses selected for the participants consisted of foot lifting or hand stroking and the microswitches used for monitoring them were tilt or touch and pressure sensors. The inappropriate posture consisted of head forward bending and was recorded through a tilt microswitch attached to a headband that the participants wore during the sessions. Like in the previous study of this section, the intervention initially focused on the adaptive response. Each occurrence of such response was followed by a brief period of preferred stimulation regardless of the head posture. Subsequently, the intervention was extended to also include the head posture. Within the new condition, adaptive responses were followed by preferred stimulation only if the participants did not have their head bending forward. Moreover, the stimulation that followed an adaptive response performed with head upward continued for the entire scheduled time only if the head posture remained correct for all that period. Otherwise, it was interrupted. All three participants were highly successful in increasing adaptive responding and decreasing inadequate head posture.

Lancioni et al. (2009e) extended the evaluation of microswitch clusters with two participants (a child and an adolescent) whose adaptive responses consisted of pushing an object with the hand or the back while their problem behavior was represented by dystonic/spastic reactions such as body arching (i.e., pushing belly and stomach forward) and leg stretching. The microswitch cluster involved two pressure sensors for one participant and a pressure sensor and a tilt device for the other participant. Initially, the intervention focused on the adaptive response. Each occurrence of object pushing would lead to a brief exposure to preferred stimulation regardless of whether dystonic/spastic reactions were present or not. Subsequently, the adaptive responses would lead to stimulation only if they occurred in the absence of the dystonic/spastic reactions. Moreover, the stimulation lasted the expected time only if dystonic/spastic expressions did not occur during that time. In line with the results of previous studies in this area, both participants showed a large increase in adaptive responding and a substantial decrease in aberrant responding.

Promoting the Performance of Ambulation Steps

Another area of application of microswitch technology has concerned ambulation. Specifically, microswitches have been used as a way to monitor the persons' step responses and eventually allow them to access preferred stimulation through the performance of such responses. In other words, microswitches were used as tools to motivate the persons' performance of those responses. The persons involved in the studies presented with multiple disabilities and used support (walker) devices. The final goal of the intervention with them was to promote their supported ambulation (Lancioni et al. 2005b, 2007d, 2010g).

For example, Lancioni et al. (2005b) used the aforementioned microswitch approach with an adolescent of 13 years of age who presented with a diagnosis of profound intellectual disability, total blindness, spastic tetraparesis, and scoliosis. He could stand and perform ambulation steps only if supported. To help him on this, a four-wheel support walker had been provided to him. His performance with this tool, however, was only modest. The notion was that his poor performance was largely due to motivation problems (i.e., disinterest in engaging in a rather demanding activity without positive/reinforcing consequences for it). To improve this situation and enhance his motivation to walk, optic microswitches were used in combination with the walker. One microwitch was attached to the right side of the walker and was to monitor the steps that the participant performed with his right foot. The other microswitch was fixed to his left shoe and was to monitor the steps the participant performed with his left foot. The microswitches were connected to an electronic control system and, during the intervention phases of the study, their activation allowed the participant to obtain brief stimulation. The frequencies of ambulation steps performed during those phases were more than twice those of the baseline periods. The participant, moreover, was reported to show indices of happiness (i.e., smiles or excited vocalizations).

Lancioni et al. (2007d) assessed the use of microswitches with two children of about 7 and 9 years of age, and two adults of 19 and 41 years of age. All participants were considered to function in the profound intellectual disability range and presented with motor impairment. They were also able to stand and take some steps with support, and were provided with four-wheel walkers. To improve their performance with the walkers, microswitches and contingent stimulation were introduced with all of them. The microswitches were two optic sensors attached to the heels of the shoes (for two participants) and a single optic sensor attached to the external side of the right leg, above the ankle (for the other two participants). During intervention, the activation of each microswitch or of the single microswitch allowed the participants to access brief periods of preferred stimulation. The general results of the study indicated that all participants had large increases in the frequencies of step responses during the intervention phases as opposed to those recorded in the baseline periods. All participants also had increases in indices of happiness (see above) during the intervention phases.

Lancioni et al. (2010g) extended the assessment of this microswitch-based approach with five children of about 5.5–11 years of age, who were diagnosed in the severe or profound intellectual disability ranges and presented with spastic tetraparesis. Four of the children also showed visual impairment. All children could perform some ambulation steps provided that they were supported by their caregivers or used their four-wheel walkers, which were equipped to support them adequately and facilitate their performance. Yet, the frequency of steps that they performed (i.e., their motivation to walk) seemed rather modest and the use of microswitches and contingent stimulation was considered relevant to bring about an improvement in their ambulation. For two of the participants, the microswitches were fixed to the right and left panels of the walker device (i.e., in positions in which they could monitor the step responses of each foot). For two other participants, the microswitches were attached to the shoes, while for the fifth participant only one microswitch was used and this was attached to his left foot. During the intervention phases of the study, the conditions were as those described in the last study reviewed above (i.e., Lancioni et al. 2007d). The results were also in line with those of the last study reviewed. That is, all five children showed significant increases in their frequencies of step responses during the intervention.

Speech Generating Devices

Speech-generating devices (SGDs) also known as voice output communication aids (VOCAs) are a form of assistive technology that allows persons without functional speech abilities to formulate verbal communication messages through nonverbal responses. The persons that can most benefit from this technology are those who (a) can only produce unintelligible speech, (b) have lost the ability to speak, or (c) have failed to develop sufficient or any speech abilities (Hemsley et al. 2001; Lancioni et al. 2012a; Sigafoos et al. 2009).

The first requirement for a successful use of SGDs for persons with severe/profound and multiple disabilities is that the persons have a reliable, effective and inexpensive (non-tiring) way of activating the device. For persons with sufficient fine motor skills, activation may involve direct selection of (e.g., pointing to, pressing, or touching) panels on the SGD connected to the request objectives. For persons who lack sufficient motor skills, one may envisage the use of simple, single sensors/microswitches (i.e., to be activated via minimal responses) connected to voice output instruments. The second requirement for a successful outcome is the availability of a communicative partner who responds to the SGD-based communication messages of the persons with disabilities in a consistent and satisfactory way, so that these persons are motivated to reproduce their communication efforts and maintain (extend) them over time (Lancioni et al. 2008b, c; Sigafoos et al. 2009).

A variety of instruments exist and multiple ways of using them have been reported (Mullennix and Stern 2010). One can envisage simple devices producing brief prerecorded messages as well as sophisticated computer technologies capable of generating multiple utterances for different situations (Mullennix and Stern 2010). Studies directed at individuals with severe/profound and multiple disabilities frequently focus on teaching the individuals to request access to preferred objects or activities. For example, Schepis and Reid (1995) used a SGD with a participant of 23 years of age, who was diagnosed with profound intellectual disabilities and extensive motor impairment, and was in a wheelchair. The device was programmed to utter four verbal request messages, which concerned four preferred items. The participant could activate any of those request messages by pressing a picture representing one of the items. The pictures were attached to the templates of the device's panel. After a brief introduction of the device, the participant had access to it for specific periods of the day. Data showed that during those periods there was an increase in requesting that was maintained over time.

Brady (2000) assessed the use of SGDs with two children of about 5 and 6 years of age, who were diagnosed with autism or severe mental retardation. The intervention concerned two daily occupational situations of the children and, in particular, making a picture or playing a tape and preparing a snack. Within each of the situations, the children could make progress (and complete the activity) by requesting the three items needed for it. The children could make the requests by pressing the pictures of the specific items they needed on microswitches connected to the SGDs. The results indicated that both children managed to carry out the request of the six items necessary for the two activity situations in which they were involved. They also seemed to acquire a satisfactory comprehension of the names of the items requested (i.e., based on the utterance of these names produced by the SGDs during the intervention sessions).

Lancioni et al. (2008c) assessed the feasibility of using a combination of two microswitches and a SGD with three participants of 10–15 years of age who had a diagnosis of multiple disabilities including severe to profound intellectual disabilities, spastic tetraparesis and lack of ambulation and of any functional interaction with objects, and blindness or minimal residual vision. The responses for the three participants consisted of small movements of hands/arms and trunk directed to specific objects/sensors, which represented (a) microswitches connected to stimulus sources (e.g., sound sources with music or specific noises and vibration devices) or (b) a sensor connected to a voice output system and thus serving for the emission of a verbal message (i.e., a request of having somebody playing with them). Intervention started with the first of the two microswitches available for each participant. When responding to this microswitch had increased and the participant had regular brief periods of access to the related stimuli, the intervention focused on the second microswitch available. When responding with this microswitch had increased, an intervention phase started with both microswitches simultaneously available. Once the participant had shown the ability to respond in this last condition, the intervention concentrated on the SGD. Activation of the SGD with the request of attention was followed by the response of the caregiver. The response was exclusively verbal (i.e., joyful sentences) for two thirds of the requests and was verbal and physical for the other third. The latter form of response involved joyful sentences as well as touching/caressing and other types of attention. Eventually, the participants were provided with the two microswitches as well as the SGD simultaneously so they could choose any of the three options. Results indicated that they were highly successful during the intervention process and chose the microswitches as well as the SGD during the last section of the program when all types of devices were available.

Lancioni et al. (2009d) assessed the combined use of a microswitch and a SGD with two post-coma participants of 35 and of 60 years of age who had been diagnosed in a minimally conscious state with extensive motor impairment. Initially, the intervention focused on a hand response connected to a microswitch. The response consisted of the contact with a touch-sensitive microswitch on the participant's leg or a hand closure activating a touch-pressure microwitch placed inside the participant's hand. Once the participants had increased their responding (which allowed them brief access to music stimulation), the intervention was concentrated on a second response connected to a SGD. Activation of the SGD led to a call for caregiver attention. The caregiver answered those calls by talking to the participants and engaging them in watching or listening to various stimuli. During the last phase of the study, the participants had the possibility of choosing between microswitch and SGD activations with musical stimulation and caregiver engagement, respectively. Data showed that both of them were successful through the different phases of the study and showed consistent microswitch and SGD responding when both of these were simultaneously available (i.e., indicating a successful combination of independent entertainment and social interaction).

Lancioni et al. (2011d) assessed the use of a commercial SGD to allow a woman with intellectual disabilities, respiratory problems, and absence of active verbal communication skills, to make requests about various activities. In relation to the single requests, the caregiver ensured (a) the availability of the material for the activity indicated by the participant, and (b) the choice between different material options. The SGD was a tablet-like tool with nine cells (Go Talk 9; Special Needs Products of Random Acts Inc., USA). Only five of those cells were used, as the participant's requests concerned five activities. Each of the five cells was provided with the pictorial representation of one activity. The response required for making requests consisted of producing a light pressure on one of those cells/representations. Such pressure activated the underlying key area and triggered the verbalization of the related message. The message consisted of calling the caregiver and asking her the possibility of engaging in one of the activities (i.e., the activity corresponding to the representation pressed). The activities consisted of: listening to music/songs, watching videos, using ornamental material, watching picture cards and completing drawings, and using make-up material. The design of the study was an AB^1BAB design in which the A represented baseline phases and the B^1 and B represented intervention phases (Kazdin 2001; Kennedy 2005). The B^1 phase was devoted to introducing the five pictorial representations used to indicate the activities available in sequence. Initially, only one representation was used. When the participant responded on it consistently, the second representation was introduced. This representation was presented individually at the start and was combined with the first one thereafter. The process of individual introduction and combined presentation continued, according to the conditions described above, until all five representations had been familiarized. The B phases included all five representations simultaneously available. This allowed the participant to request any of the activities. An activity was made possible (through the material among which the participant could choose) for about 2 min after each request. During the baseline phases, only few requests were made by the participant (and understood by caregivers and staff). During the intervention phases, by contrast, an average of about eight requests occurred per 20–25 min session.

Indoor Orientation Systems

Orientation and mobility problems within indoor daily contexts are quite frequent for persons with or without severe visual impairment or blindness who are affected by disabilities, such as severe and profound intellectual disabilities or degenerative neurological syndromes (e.g., Alzheimer's disease) (Gadler et al. 2009; Joffee and Rikhye 1991; Lancioni et al. 1995a, b, 2000a, b, 2010d, f, 2011b; Marquardt and Schmieg 2009; Provencher et al. 2008; Uslan et al. 1983, 1988). Indoor orientation problems can have serious negative consequences for these persons and, specifically, can limit their prospects of (or prevent them from) independent activity engagement, confine them to specific spaces without possibility of exploring, hinder any self-assurance, and depress their developmental and social opportunities (Algozzine et al. 2001; Karvonen et al. 2004; Konrad et al. 2007; Lachapelle et al. 2005; Lancioni et al. 2000a, b; Petry et al. 2005, 2009; Provencher et al. 2008).

Given the negative consequences of orientation and travel problems, strong consensus exists about the need to find strategies that contain those problems and improve the general situation of the persons affected by them (Draheim et al. 2002; Gibson et al. 2004; Higgerty and Williams 2005; Lancioni et al. 2012a; Rainville et al. 2001). The technology-assisted strategies suggested for this purpose essentially include (a) auditory maps, (b) orientation systems based on direction cues, and (c) orientation systems based on corrective feedback (Cherrier et al. 2001; Guth and LaDuke 1994, 1995; Joffee 1995; Lancioni et al. 1993a, b, 1994, 2010d; Martinsen et al. 2007; Uslan et al. 1983, 1988). The use of auditory maps, namely, of verbal descriptions of the environment in which the person has to travel in order to provide him or her cues and guidance, and thus enable him or her to reach the destination, may not resolve the problems mentioned above. To the contrary, it could even complicate matters further, given the fact that most of these persons could not be expected to possess the ability to discriminate and utilize verbal cues (Lancioni et al. 2008a).

The orientation systems constitute technological resources adequate to overcome the problems left open by the auditory maps (Baldwin 2003; Lancioni et al. 2012a; Parker 2009; Ross and Kelly 2009). Research in this technology area started with Uslan and his associates (Uslan 1976; Uslan et al. 1983, 1988) who designed an orientation system including auditory (musical) stimuli as spatial cues for helping persons with visual and intellectual disabilities travel in their indoor environment. It included (a) a central electronic unit allowing the selection of the destinations to be reached, (b) electronic floor sensors that were triggered by the participants while walking on them (and as a result activated auditory/musical cues), and a number of loudspeakers, which were along the routes to the destinations and served to emit the cues. The encouraging results obtained with this system and the reservations about its applicability and overall practically (i.e., given the fact that the system for selecting new destinations was not portable and the participant and caregiver were always to return to a starting point) sparkled a series of research studies on new orientation systems (Lancioni et al. 1993a, b, 1994, 1995a, b, 2010d).

The first requirement to be satisfied in the development of the new systems was that they should allow the selection of a new destination from any corner of the indoor space within which the person was to orient and travel. In the development process, the basic reasoning was that different persons could need different levels of support. For example, persons with blindness and generally low functioning abilities (i.e., showing a very limited notion of space and virtually no orientation skills) would be likely to need a system that does not require much initiative and self-direction from them (Lancioni et al. 2012a). Such a system could be conceived as one that presents direction cues, that is, cues that orient and support the person's travel to the destination (Lancioni et al. 2010d). On the contrary, persons with functional (residual) vision and a general notion of the spatial reality surrounding them would be expected to need a system that is less intrusive than the one mentioned above (Lancioni et al. 2012a). This latter system would not involve the use of directive cues, but would simply rely on corrective feedback. Specifically, the system would (a) allow the person to engage in travel using his or her self-management and initiative skills (Lancioni et al. 2012a) and (b) intervene only if the person happened to deviate from or lose the correct direction. In that case, the system would provide a feedback lasting until the person managed to find back the correct direction and thus could travel successfully.

Orientation Studies with Direction Cues

As indicated above, orientation systems relying on direction cues require the persons to follow those cues (i.e., to walk toward them) to reach the destination (Lancioni et al. 2000a, b). Most of the studies reported in the literature have adopted auditory signals as cues. Such signals consisted of complex (buzzer-like) sounds or verbal messages (Lancioni et al. 1995a, 1997b, 1998a, b, 1999a, 2008d, 2010d, f, 2011b). A few studies also assessed the use of visual cues (lights) (Lancioni et al. 1996, 1998a, b, 2000b, 2013).

Studies with auditory cues. Lancioni et al. (1995a) reported the first attempt to improve on the early work by Uslan et al. (1988) in a study involving four adolescents between 12.5 and 15 years of age who were totally blind and were considered to be functioning within the profound intellectual disability range. The four participants were to travel to several indoor destinations for their daily activities. None of them seemed particularly versatile in dealing with this requirement and extensive caregiver assistance was needed. The technology developed for the study involved a portable electronic control device and a variety of acoustic sources, which were displayed along the routes to the different destinations. The portable device, which was worn by the participants at their chest, included keys with the numbers zero to nine on them for the selection of the routes to the destinations. In practice, the staff personnel supervising the sessions were to press two of those keys (i.e., the numerical code) of the route that the participant was to follow to reach the next destination before he started to walk toward it. This selection operation could be carried out from any place of the setting (rather than from a central area, as it occurred in the studies by Uslan et al. 1983, 1988). Once the route had been entered, the first acoustic source available on that route was activated and it emitted brief harmonic sounds of about 360 Hz, which were alternated with brief silence intervals. When the participant reached the source, the portable device deactivated it so that the next one in the route could be activated. The process was repeated until the destination was reached. Results showed that all four participants improved their performance reaching percentages of correct travel of near or above 90.

Lancioni et al. (1997b) assessed the feasibility of using verbal cues (i.e., spoken messages) instead of buzzer-like sounds such as those mentioned above with two participants of 17 and 19 years of age. The use of spoken messages was considered important to make the cues less artificial (more natural and humane). They consisted of two to four words (e.g., the name of the participant and a word of encouragement). The messages were recorded by a person familiar to the participants and were emitted by the sound sources displayed along the routes to the destinations (see above). Messages were alternated with brief periods of silence until the participant had reached the destination. During the study, the system was used as a tool to assist the participants through a series of small activities. In order to promote participants' total independence (i.e., to avoid the need for the supervisor to enter the destination code in the portable device before each travel), new technical and practical solutions were adopted. First, the portable control device was preprogrammable. That is, a number of routes/destinations could be entered in a specific sequence and would be activated, one at a time in the right sequence, by a simple pressure on the front panel of the device. Second, conditions were created for the participants to perform the aforementioned pressure response after the completion of each activity. In fact, they would always find a Velcro tag serving as a token together with the objects for a new activity to be performed at the next destination. They would attach the Velcro tag to the front panel of the portable control device (with the possibility of exchanging it for a reinforcing event at the end of the session) and, by doing so, they would activate the next destination and the sound sources leading to it. The study showed that both participants learned to use the technology package independently and with the help of the spoken cues reached a percentage of correct travels exceeding 90.

Lancioni et al. (2010f) assessed a new portable device within an orientation program for two women of 24 and 21 years of age, with the aim of facilitating a successfully independent use of such device and thus fully independent travel and activity engagement. During each session, the women were to travel to six different destinations in order to carry out six familiar activities (one per destination). The technology package involved the presence of a sound source at each of the destinations and a new portable device. This device consisted of a box-like instrument that the participants had at their chest. The main (external) face of such box included six key areas, which corresponded to the six destinations to reach (the six activities to be performed) within a session. Each of the key areas was marked by the presence of an embedded optic sensor, which was covered by a small, discriminated object replica representing an activity available at one of the destinations. By removing/detaching an object replica (i.e., uncovering a specific optic sensor), the participants activated the sound source displayed at the destination where the corresponding activity was to be carried out. The sound source emitted brief encouragement messages until the participants reached the destination. The participants could follow any sequence they wanted in detaching the object replicas from the box and, thus, they were free in determining the order with which they carried out the activities available. Both of them managed to use the system efficiently (and in particular learned to use the new portable device rapidly), gaining the ability to reach the destinations and carry out the activities available there.

Lancioni et al. (2011b) assessed the applicability of a basic version of the orientation program with spoken messages as direction cues for three participants with Alzheimer's disease. The participants were between 73 and 83 years of age and had lost their abilities to orient to activity places as well as to carry out daily activities. All three participants attended a day center in which they were provided with some form of support for promoting positive engagement. The orientation program was to help them walk to different rooms of the center to engage in small activities or simply meet people. A very basic version of the program was used. This required that the supervisor activated the target destinations (one at a time) in the portable device and only one sound source per destination was available. Two of the participants seemed able to orient to the spoken encouragement messages/cues emitted by the sound sources and thus were introduced into the program directly. One participant showed difficulties orienting to those messages/cues and was provided with a preliminary form of intervention in which (a) the supervisor presented the messages with her voice superimposed to the recordings of the sound sources and eventually faded her voice out and (b) the cues were repeated more frequently. Data showed that the first two participants were highly successful in using the system's cues from the beginning of the intervention and maintained a highly successful performance thereafter. The third participant benefited from the initial intervention phase (with the help of the supervisor's voice) and subsequently displayed a successful travel performance comparable to that of the other two participants.

Studies with visual (light) cues. Lancioni et al. (1996) carried out the first evaluation of the applicability of visual cues as orientation means for persons with multiple disabilities. Visual cues were deemed a potentially important resource for persons who have some levels of visual ability even when such levels are limited or minimal as well as for persons who have auditory impairments (Lancioni et al. 1996, 2012a). The participants were two young men of 18 and 19 years of age who had a diagnosis of profound intellectual disabilities and severe visual impairment. The portable device for the selection of the destinations was similar to that used by Lancioni et al. (1995a) and thus required the intervention of the session supervisor. The light sources displayed along the routes to the destinations were radio linked to the portable device and contained two lamps, which emitted approximately one flash per second when activated. The selection of a destination through the portable device activated the first light box available on the way to the destination. When the participant reached such box, the portable device deactivated it so that the next one in the route could be activated (i.e., the same way as with the sound sources). The process was repeated until the destination was reached. Both participants were highly successful in using the system. Their percentages of correct travels increased to means of near or above 90 with the help of it.

Lancioni et al. (2000b) extended the assessment of the orientation system with visual cues to a 35-year-old woman. The participant's use of the system to travel and carry out activities was also to serve as a form of exercise intended to improve her general physical condition in addition to increasing her adaptive engagement. Both these objectives were deemed important because the woman was reported to be passive and sedentary as well as overweight. The woman's program generally involved two 30-min sessions in the morning and two 30-min sessions in the afternoon. Data showed that she learned to use the system and maintained its use over a relatively long period of time. Moreover, the travel and activity (i.e., exercise) seemed to have positive effects on the woman's physical condition. She had reportedly increased her ability to rise from a squatting position with reduced amount of help (i.e., showing an apparent improvement in muscle strength). She also had a reduction in the excretion levels of urinary calcium and urinary hydroxyproline (i.e., showing a possibly improved bone metabolism with potentially long-term effects on bone mineral density). Finally, she displayed a body weight reduction without exposure to special diets. This last point was viewed as another important benefit in an area of concern (i.e., body weight) for many persons with intellectual and multiple disabilities.

Orientation Studies with Corrective Feedback

As indicated above, orientation systems relying on corrective feedback are considered the strategy of choice for helping persons with traveling initiative and relatively adequate spatial knowledge. Such a strategy would respect these individuals' self-determination and freedom and, at the same time, would ensure that they receive assistance if needed, with the guarantee of a successful outcome (Lancioni et al. 1997a, 2005b; Lancioni and Mantini 1999).

For example, Lancioni et al. (1997a) assessed the effectiveness of an orientation system with corrective feedback with a 38-year-old woman who had a diagnosis of total blindness and severe intellectual disability with a Vineland age equivalent of about 3 years on her daily living skills. She was apparently interested in engaging in simple activities but required some assistance in traveling across activity destinations within her daily context. The orientation system developed for her included small boxes emitting ultrasonic waves, which served to trace (mark) the routes from one activity destination to the other, and a portable control device connected to earpieces. The portable device was interacting with the aforementioned boxes and presented verbal praise or a buzzer feedback through the earpieces depending on whether her walking direction was correct or incorrect. Each travel started with the woman taking an object indicating the activity that was to be carried out and attaching the Velcro tag available with that object to the front panel (input/activation section) of the portable device. Attaching the Velcro (pressing the front panel of the device; see above) activated a destination and the emission of praise or buzzer feedback. In case of a buzzer sound (in case of direction error), the woman was required to turn until the sound stopped. At that point, she was expected to restart her walking process. The woman learned to manage the system profitably, and she became rapidly independent with high percentages of correct travel performance.

Lancioni and Mantini (1999) extended the research in this area with a 30-year-old woman who had a diagnosis of minimal residual vision, deafness, and profound intellectual disability. The orientation system used with her included a variety of boxes emitting ultrasonic waves, such as those described above for the study by Lancioni et al. (1997a), and a portable device combined with a feedback case. The procedural sequence matched that described for the study mentioned above, but the portable device worked in a different way. Specifically, it (a) kept totally silent during the time in which the woman walked within the route lines available for the destination selected, and (b) presented vibratory feedback in case the woman strayed out of those lines (i.e., if the woman diverged of about 20 degrees from the direction considered correct). In the latter situation, the woman was required to turn to her left (i.e., following the vibration feedback that she received on the left side of her body), until the vibration stopped. Once the feedback had stopped, she could resume her walking to the destination. Data showed that the woman was highly successful in using this technology and her percentages of correct travel increased very rapidly and remained consistent.

Instruction Systems for Activities

Constructive (functional) activity engagement is an important goal of programs for persons with severe to profound intellectual disabilities with no main motor impairment, that is, without specific body limitations that would interfere with their object use (Taylor and Hodapp 2012). Activity engagement would increase the persons' positive occupation with beneficial effects in terms of general stimulation, reduction of negative incompatible behavior, and improvement of social status. The acquisition of activity skills, however, remains a difficult goal for many of those persons. In fact, they may have problems in remembering the steps of the activities that they are to perform. They may also have problems in being motivated and thus being willing to engage in the activity with continuity and resolution (Harr et al. 2011). The overall consensus existing on the importance of establishing successful activity performance has sparkled several intervention initiatives. Most studies have been concentrated on the development of instruction systems that could help the persons go through the activity steps effectively in spite of their memory and attention limitations (Ayres and Cihak 2010; Davies et al. 2002).

The most largely acknowledged instruction strategy set up for these persons has consisted in the use of pictorial cues arranged in some form of booklet or other sequential display (Furniss et al. 2001). To reduce problems connected with the handling of cards, computer-aided instruction strategies have also been reported (Ayres and Cihak 2010; Lancioni and Oliva 1988), and a number of comparisons have been carried out between computer-aided instruction presentations and booklet-style instruction presentations (e.g., Furniss et al. 2001; Lancioni et al. 2000c). More recently, attention has been directed at the possible relevance of a dynamic visual instruction procedure (i.e., video prompting) (Banda et al. 2011; Mechling and Gustafson 2009).

For example, Lancioni et al. (2000c) extended (a) their evaluation of the suitability and efficacy of computer-aided pictorial instructions for functional activities and (b) their comparison of these types of instructions with pictorial instructions presented via cards collected in booklets. The participants were three men and three women whose ages ranged from 23 to 47 years. All participants were ambulatory and had some verbal communication abilities. They lived in residential facilities and attended day activity centers where they were involved in some occupational and recreational programs with the availability of external support. Although no IQ scores were available for them, their psychological records classified them as persons with severe intellectual disabilities. They were able to discriminate simple pictorial representations and could recognize the objects portrayed by those pictures. A palm-top computer with color screen was supplemented with an electronic circuitry for the emission of prompts and stored inside a box with only two elements visible/available to the participants, that is, the screen in which the pictorial instructions appeared and a single (large) key through which the participants would request each new instruction. The instructions for a task consisted of 25–31 simple representations (i.e., color drawings) indicating the task steps. These representations were interspersed with four to six other representations (i.e., smiling faces), which signaled reinforcing instances. The card instructions for a task matched those available via the computer system and thus included step instructions as well as smiling faces instructions.

Each participant was provided with eight tasks, four concerned cleaning and table setting while the other four concerned food preparation. After the baseline phase, each participant was exposed to an intervention phase in which computer-aided pictorial instructions were used for one set of tasks and card instructions for the other set of tasks. The intervention phase was introduced by several familiarization sessions with each of the two instruction strategies. During the sessions that followed the participants were to seek/manage and respond to the instructions on their own. To seek a new computer-aided pictorial instruction, the participants were to press the single key of the computer system. The system would ignore erroneous/repeated pressure responses. Moreover, it would send out a prompt if the participants failed to seek a new instruction within a maximum preset time from the occurrence of the previous instruction. In relation to the smiling faces instructions, the participants were to call the experimenter who would provide some form of reinforcement. The experimenter also intervened in case of errors or failure to carry out steps. Usually 40 sessions per condition were available. Then, a crossover test occurred. That is, the tasks previously presented with the computer-aided pictorial instructions were presented with the card instructions and vice versa. Intervention data showed that all six participants had higher percentages of correct performance on the tasks presented with the computer-aided pictorial instructions. Crossover data indicated that participants had clear improvements in the performance of the tasks transferred from card instructions to computer-aided pictorial instructions and vice versa.

After the completion of the aforementioned assessment, (Lancioni et al. 2000c) also explored the possibility of reducing the number of computer-aided instruction occasions available for the tasks. This initiative was taken with three of the six participants, that is, those with the most successful level of performance. In one of the conditions, about two thirds of the instructions were presented in clusters of two rather than individually. The first instruction of a cluster was presented for 1 s and then replaced automatically by the second instruction, which remained in view on the screen (e.g., a milk carton appeared for 1 s and then was replaced by the image of the carton in a horizontal position over a bowl, indicating the action of taking the milk carton and pouring the milk into the bowl). In the other condition, the first representation of the clusters was simply omitted. The participants' performance with the clusters seemed to be largely comparable to their performance with the instructions presented individually and consistently better than their performance in the condition in which a number of instructions were omitted.

Cannella-Malone et al. (2011) compared the effects of video prompting and video modeling in teaching seven school children of 11–13 years of age two daily living tasks, that is, starting a load of laundry and hand-washing a plate, spoon, and cup. The two tasks were considered comparable in terms of difficulty and had the same number of steps (i.e., 18). The children were diagnosed with moderate to severe intellectual disabilities and six of them also with autism. For the video prompting version of each task, 18 video clips were prepared. Each clip showed one step of the task. For the video modeling version of each task, a single video was made which illustrated all 18 steps of it. During intervention sessions with video prompting, the participants were shown one instruction at a time and allowed 30 s to complete it. If they failed to carry it out the research assistant could provide various levels of prompts. During intervention sessions with video modeling, the participants had 30 s to start the first step and 2.5 min to carry out the following steps. The results indicated that video prompting was more effective than video modeling in teaching the tasks even though not all participants were able to achieve full task mastery.

General Considerations on the Technological Resources Reviewed

Microswitches. Intervention programs with microswitches may be very helpful for (a) promoting adaptive responding and positive occupation, (b) combining adaptive responding and occupation with the reduction of problem postures and behavior, and (c) enhancing basic levels of ambulation. The results in each of these areas have been quite encouraging and this can motivate a cautious increase of attention toward these types of resources within applied education/rehabilitation settings for persons with severe/profound intellectual and multiple disabilities. The use of these resources can be effective only if a number of conditions are met. The first condition is the selection of a response (or responses) that can be relatively simple (non-tiring) and reliable for the person and of a microswitch device (or microswitch devices) that can monitor the response(s) successfully. The second condition concerns the availability of environmental events/stimuli that the participants want to reach, manipulate, and enjoy through the use of the microswitch(es). Absence of these events/stimuli would preclude any initiative of the participant in getting engaged thus any opportunity of positive change. The third condition concerns the choice of the program that best suits the person (e.g., use of single or multiple microswitches) and the development of such program in line with the participant's progress.

Additional considerations about programs with microswitch technology may be related to (a) their frequently reported, positive effects on the persons' mood, (b) the favorable view of staff and families about them, and (c) the need of technological upgrading/updates to expand their suitability. The positive effects of microswitch programs on the participants' mood have often been documented as an increase in the participants' indices of happiness (Lancioni et al. 2006d, e, 2007c). This is a critically important aspect of those programs (Dillon and Carr 2007). In fact, (a) one might consider happiness as the most significant indicator of an improved (satisfactory) quality of life and (b) improving the participants' quality of life can be considered a priority of any microswitch-aided intervention program (i.e., a goal as big as or bigger than the learning and occupation pursued by the program) (Szymanski 2000).

With regard to the second point, one may refer to the social validation data collected with 140 teacher trainees and 84 parents in a study by Lancioni et al. (2006a). Both these groups of persons rated microswitch-based programs largely preferable to conventional interaction or stimulation conditions for participants with multiple disabilities. The rating was carried out on a seven-item questionnaire concerning the participants' apparent enjoyment of the two conditions, the possible impact of those conditions on a personal/developmental and social level, and the raters' own view on the likeableness (acceptability) of those conditions.

With regard to the need of technological updates, one refers to the relevance of finding/providing more satisfactory designs for the available microswitches or developing new forms of microswitches. One example of recent, innovative development in this area is represented by the camera-based technology that allows the possibility of monitoring small responses through the use of one or two color marks rather than through more invasive devices (Lancioni et al. 2010a, 2011a). Finding new response-microswitch combinations may be important to create intervention alternatives that could facilitate the progress of persons only marginally suitable for the use of the combinations available or unlikely to benefit from any of those combinations.

Speech generating devices. Programs based on the use of these devices can be considered a great opportunity to enhance effective communication in persons with limited or no resources in this area. Successful outcomes from the application of these programs would largely depend on (a) how well the technology matches the characteristics of the persons involved as well as on (b) how suited the intervention procedures are for helping the participants learn the use of such technology. The two main ways of using this technology may be represented (a) by making requests of items and activities that the participants want to obtain but are unable to reach independently and (b) by calling for personal attention. The first option can be highly useful in a variety of daily situations in which the participants may learn to communicate their requests and gain access to events that can be reinforcing and motivating for them. For example, one can envisage this kind of approach in snack situations as well as in play or occupational situations (Sigafoos et al. 2009). The second option can be highly useful in situations in which the participants can access little interactive games or activities or simply some physical and verbal attention through the involvement of their caregivers (Lancioni et al. 2012a).

A particularly interesting approach seems to be the combination of microswitches for the participants' direct access to stimulation and SGDs for the participants' request of attention from their caregivers. This kind of approach would seem to have two clear merits. First, it would allow one to overcome possible isolation risks connected to programs involving only the use of microswitches. Within such programs the participants can engage in activity and access stimulation, but do not have opportunities to interact with their caregivers and thus could be socially frustrated. Second, it would require the caregivers a less frequent/intense availability than programs involving only the use of SGDs. A less frequent/intense availability would be more easily reconcilable with other supervising and management duties of the caregivers within the context. The possibility of reconciling such an approach with the common duties could enable the caregivers to apply it for longer and repeated periods of the day without practical and organizational problems. Obviously, a more extensive use of the approach could have large beneficial effects for the participants giving them extra opportunities of positive engagement, stimulation input, communication, and social interaction.

Indoor orientation systems. Programs based on orientation systems might represent the only way for a large section of persons with intellectual and multiple disabilities as well as neurodegenerative diseases (e.g., Alzheimer's disease) to manage independent indoor travel. This type of independence might be critical to allow these persons higher levels of motor exercise (ambulation) with beneficial effects for their functional activity engagement as well as their physical condition. Using an orientation system to carry out a series of daily activities over different spaces/rooms may easily be viewed as a positive (and socially and personally preferred) alternative to engaging in a few activities within a small space (Lancioni et al. 1999b, 2012a). Orientation programs, like any other programs, need to be geared on the abilities of the persons involved. Programs directed at persons with profound intellectual and visual impairment would almost necessarily have to rely on the use of direction cues, that is, cues that are aimed at providing directive guidance to the participants and leading them to the destinations. By contrast, programs directed at persons with some sense of spatial organization and possibly functional residual vision could easily rely on corrective feedback. These programs would allow the participants ample opportunities of independence and self-determination and intervene only in case of direction errors trying to help the participants correct such errors and resume the correct travel direction.

The positive data obtained with the two groups of programs (i.e., with the direction cues or feedback used to help the persons manage successful travel) should be analyzed in relation to the portable device adopted in the programs. The first/basic requirement for the portable device was that it should allow the selection of new destinations from any area of the setting in which the participants were. The research assistant could enter the destination/route code into the device. The second requirement (which became increasingly important) was that it should be designed to allow the participants to enter the destinations independently so that they could move from an activity to another during an entire activity session. To achieve this objective (i.e., enable the participants to enter the destinations and thus reach full independence), the studies have assessed different forms of portable devices. One of the devices (suitable for fairly advanced persons) had the key areas covered by small object replicas corresponding to the activities to be carried out at the destinations. The person needed to remove one of those objects to activate a specific destination (Lancioni et al. 2010f). Another type of device (used extensively with participants with relatively low level of functioning) consisted of a box with a front panel serving as an input/activation tool. A simple response of the participants such as attaching a Velcro tag to it activated the next destination of the sequence prearranged for the work session (e.g., Lancioni et al. 1997b, 1998a, b). A third type of device developed and assessed in studies not reviewed in this chapter (and suitable for persons with very low levels of functioning) worked on a time schedule. It activated each new destination automatically. Any of them was activated after a preset interval of time has elapsed from the participant reaching the previous destination of the sequence (e.g., Lancioni et al. 1999a).

Instruction systems for activities. Programs aimed at helping persons with severe intellectual and multiple disabilities to carry out functional activities can be considered critical to provide those persons a relevant role within their domestic, educational or work environment. The technology used for helping them achieve such a goal may be decisive in determining their success or the lack thereof. The first of the two studies reviewed has underlined (a) the great impact of pictorial instructions presented through computer-aided packages requiring a simplified response to request the next instructions (and including reinforcing occasions, and prompt opportunities), and (b) the possibility of combining the instructions in small groups on a later stage of the intervention/maintenance. The latter point appears very attractive since it represents the first data demonstration that fewer instruction occasions can become eventually sufficient for the persons to carry out the activity without compromising their level of accuracy. Obviously, this evidence needs to be replicated with additional participants and across different tasks and contexts.

The second study reveals the great potential of video prompts as instructions. Video prompts could be envisaged as forms of dynamic visual instructions that represent (a) a substantial variation of the static pictorial representations assessed in the study by Lancioni et al. (2000c) and several other studies conducted prior to or in the proximity of that study (e.g., Furniss et al. 1999, 2001; Lancioni et al. 1988) and (b) an alternative to video modeling, with larger applicability and efficacy with persons with severe/profound intellectual and multiple disabilities (Bidwell and Rehfeldt 2004). The basic assumption concerning the use of video prompting is that it might be more informative and transparent than either of the other two strategies and thus could represent a relevant resource for applied settings. The available data cannot provide a definite answer on this question. At present, one might speculate that video prompting could serve as an effective strategy for those participants who are able to analyze the single video clips (video sequences) and imitate each of them in reality. Speculations need to be confirmed or confuted by research data collected for individuals exposed simultaneously to two of the approaches (e.g., video prompting vs. video modeling and video prompting vs. static pictorial instructions) (Banda et al. 2011; Cannella-Malone et al. 2011; Mechling and Gustafson 2009).

Conclusions

The studies reviewed in this chapter have provided an encouraging account of a number of technological resources available for persons with severe/profound intellectual and multiple disabilities. Microswitch technology and microswitch-aided intervention programs have been widely assessed in a variety of different formats and directed at different goals. Based on the findings, one can argue that even persons with minimal motor behavior and no apparent interaction with the outside world may be helped with this type of technology. Two questions that may be considered important for new research in this area concern the: (a) development and assessment of new microswitch devices for minimal responses and (b) the assessment of programs including clusters of microswitches (Leung and Chau 2010; Lui et al. 2012). From the first type of research, one would expect new solutions to help persons who do not yet find practical/effective help using the resources available. From the second type of research, new evidence would be acquired on the effectiveness of the approach with responses already targeted as well as with new response combinations (Lancioni et al. 2009c, 2012a).

The use of SGDs may allow communication opportunities with important practical and social implications for the participants involved. Functional forms of communication may concern the request of (a) items and activities that the participants want to obtain but are unable to reach independently and (b) caregiver attention. For a number of cases, the request of caregiver attention could be pursued not as the only objective, but as an objective combined with that of accessing preferred stimulation through microswitch activations. Such an outlook seems quite advantageous for the participant as well as for the caregiver. New research with additional participants and various combinations of microswitch devices for stimulation access and SGDs for the request of caregiver attention could be useful to extend the evidence available and determine its generality across individuals and contexts.

The use of orientation systems can be the only way to help persons with profound and multiple disabilities travel within their daily contexts independently. The importance of this independence can hardly be overemphasized. In fact, independence may be the prerequisite for increased opportunities of ambulation (and physical exercise) and occupational engagement. Different orientation systems are available for persons with different level of functioning and spatial awareness. Data have shown a specific role for each system. New research could explore the possibility of developing a system that can be somewhere between the one relying on direction cues and the one relying on corrective feedback. For example, one could envisage a system that provides feedback but can also give direction cues if the participant is slow in correcting his or her direction or shows recurrent errors.

The use of instruction systems is critical to support the performance of complex (multistep) activities/tasks in persons with severe intellectual or multiple disabilities. Enabling those persons to carry out complex and functional tasks amounts to providing them a relevant position within their contexts and thus increasing the respect and attention they receive from people around them (Cannella-Malone et al. 2011; Furniss et al. 2001). The systems reviewed in the chapter seemed suitable and largely encouraging in terms of overall impact. New research could help determine the true value of video prompting as opposed to static pictorial instructions. With that information available, it could be possible for one to decide ahead of time which participants would benefit more from one system and which participants would do better with the other system. The possibility of gradually reducing the instruction occasions without compromising the participants' performance seems to be relevant technically as well as practically and could be considered another relevant issue for research.

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Index

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