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Assistive Technologies for Cognitive Disabilities

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ABSTRACT: Purpose: To provide a comprehensive review of assistive technology (AT) to offset cognitive impairment, including examples, with pros and cons and important considerations for AT selection. **Method**: Prior research and a literature review identified the critical need for a means to identify key elements known to influence the successful use of AT and other supports by persons with cognitive disabilities. **Results**: The components of effective and satisfied AT use result from a good match among device features, user goals and preferences, and environmental resources (including trained professionals and providers). **Conclusions**: As the number of AT options increase, individualized interventions for individuals with cognitive disabilities will be easier to accomplish. The key to successful and optimal use of these products will be a comprehensive yet individualized determination of consumer needs and preferences and the identification of additional accommodations and supports.

KEY WORDS: assessment, assistive devices, brain injuries, cognitive disabilities, cognitive orthoses, cognitive rehabilitation, functional capabilities, neurorehabilitation, outcomes research, technology

I. ASSISTIVE TECHNOLOGIES FOR COGNITIVE DISABILITIES

The combined prevalence of all individuals living with cognitive disability in the United States is 20 million or about 7% of the population.[1] Cognitive disabilities are clinically complex—each having unique effects on an individual that often change over time, sometimes rapidly. Diagnoses that have cognitive disability as a primary characteristic include the following:

- Acquired medical conditions, such as traumatic brain injury (TBI), stroke /aneurysm, brain cancer, and anoxia. According to the Brain Injury Association, the prevalence of traumatic brain injury alone is approximately 5.3 million across all ages, with an annual incidence of 1.5 million.[2]
- Brain deterioration related to progressive disease processes (eg, Multiple Sclerosis, Alzheimer's Disease, and other dementing illnesses).
- Learning and intellectual disabilities, often associated with developmental disabilities such as attention deficit disorder/attention deficit hyperactivity disorder, mental retardation, autism spectrum disorders.
- Chronic and severe mental illnesses, such as schizophrenia.

Some cognitive disabilities are transient and relatively mild, affecting only one or two areas of function. Others, however, require intervention

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for significant, long-lasting deficits in areas such as attention, learning and memory, and planning that have a direct impact on daily functioning. Cognitive deficits affecting memory and organization that typically follow moderate and severe TBI, for example, include difficulties with prospective memory, recall of everyday events, and learning new information.[3,4] These difficulties affect a wide range of everyday activities and relationships, resulting in reduced participation in social/vocational activities and loss of personal independence.[5,6]

Cognitive interventions may also need to take into account multiple areas of functioning because of interactions among deficit areas. For some individuals, physical difficulty may have an impact on cognitive efficiency. For example, focusing one's attention exclusively on performance of a physical task that is very demanding, such as walking with an ataxic gait, may result in distraction from a cognitive task, such as attending to vehicles approaching from the left. In such cases, a cognitive intervention may be of most value if it is offered at a time when the likelihood of distraction associated with physical tasks is most likely to occur (eg, community ambulation), but it may not be needed at other times (eg, watching television), when the demanding physical activity is not required. Conversely, for other individuals, difficulty with sustained memory or attention may have an impact on performance of tasks that emphasize use of otherwise intact motor or sensory systems. For example, an individual with memory impairments may suddenly experience increased accidents at work when faced with new tasks that are difficult to learn, or an individual with attentional deficits may become unacceptably messy during meals, despite intact upper extremity functioning, when the dining room is too noisy. In such cases, an assistive technology for cognition (ATC) intervention may be most useful if it provides cues about how best to perform the motor tasks, rather than offering cues that are directed at the cognitive impairment itself (eg, "when installing the large bolt, remember to keep your left hand under the work bench"). Other factors, such as fatigue, pain, and depression, may exacerbate difficulties in the above areas or be exacerbated by a person's recognition of cognitive changes. And, of course, each person with a cognitive disability is an individual with a unique combination of needs, preferences, emotional reactions, and support system. Given this complicated picture, it is crucial that rehabilitation providers understand how to work with the individual with cognitive disability to assess both strengths and weaknesses, and to devise an optimal balance of supports and accommodations that have been customized to the individual's needs.[7–9]

The purpose of this article is to discuss some conceptual frameworks that may be useful for developing or prescribing assistive technologies (AT) to offset cognitive disabilities, and to describe some of the newer cognitive AT methods that have appeared in recent clinical and research literature. It is beyond our scope to consider all types of cognitive disability in this discussion or to explore the entire universe of AT as it relates to cognitive disability. We have selected particular areas within the current authors' expertise and hope that the points we draw will be applicable, as well, to other areas. In the discussion that follows, most of our attention is devoted to the use of cognitive AT within a rehabilitation context, which means cognitive AT mainly for acquired disorders and mainly for adults. We begin with a general discussion of intervention approaches, AT, and disability, in general, and then move to specific discussions of research and practice related to AT for cognitive disabilities.

II. INTERVENTIONS FOR COGNITIVE DISABILITIES

Because of the central importance of cognition for adaptive functioning in the home, school, and community, cognitive disabilities are specifically targeted in most comprehensive rehabilitation programs. Although clinical interventions for cognitive problems are in wide use, actual evidence for their effectiveness constitutes a work in progress. Cicerone and colleagues[10] did a literature review of studies reporting the result of interventions for cognitive disabilities due to TBI or stroke and determined that specific recommendations can be made for remediation of language and perception after left and right hemisphere stroke, respectively, and for the remediation of attention, memory, functional communication, and executive functioning after TBI. More recent research by Cicerone and colleagues[11] has judged intensive, holistic, cognitive rehabilitation to be an effective form of rehabilitation, particularly for persons with TBI who have previously been unable to resume community functioning despite standard neurorehabilitation. The authors further conclude that perceived self-efficacy may have significant impact on functional outcomes after TBI rehabilitation and that measures of social participation and subjective well-being appear to represent distinct and separable rehabilitation outcomes after TBI. Given the importance of self-efficacy, the control and independence offered by assistive technologies have the potential to positively affect the rehabilitation outcomes of social participation and subjective well-being. Thus, the findings reported above support the belief that persons with cognitive disabilities require and can benefit from a number of supports, many of which can be provided by assistive technologies and adapted computer technologies.

In summary, by enabling a person to perform desired tasks, it is possible that assistive technologies may provide a sense of competence and reconnection to the community. By accommodating a person's weaknesses and supporting his or her strengths, assistive technologies can reduce psychosocial stressors, thus leading to renewed confidence, self-efficacy, and self-esteem.[7,12]

III. AT AND AT FOR COGNITION

In the United States, assistive technology was first defined in the 1988 Technology-Related Assistance for Individuals with Disabilities Act (or Tech Act, PL 100-407), which was reauthorized in 1998 (as PL 105-220) as the Assistive Technology Act and reauthorized again in 2004 (PL 108-364)

> Any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities.

As implied by the name, ATC is a special subclass of interventions that is designed to "increase, maintain, or improve functional capabilities" for individuals whose cognitive changes limit their effective participation in daily activities. Broadly defined, assistive technology for cognition could refer to very familiar, basic devices used by people with and without disabilities to support memory, organization or other cognitive functions, such as planner books, calendars, wristwatches, and shopping lists. Simple and low-cost devices such as magnifying lenses, index cards, and timers/alarm clocks and even cell phones can promote independence and improve the individual's quality of life.[13–15] As discussed in more detail below, there are also specialized devices that use computer software and networking capabilities to offer much more sophisticated support to the cognitively impaired user. These newer, specially designed ATC devices have features that can (1) maintain, organize, and facilitate access to information; (2) present suggestions, instructions, or corrections to the user—either on demand or at prescribed times; (3) assume responsibility for task components that have proven too complex for an individual to complete independently, so that activities in which those components are embedded can be successfully completed; (4) provide more comprehensive interactive guidance for tasks that are too difficult for the user to initiate or perform, even with other types of modifications and compensatory strategies; and (5) monitor the quality of the user's task performance so that errors can be tracked and the ATC intervention subsequently modified in an attempt to reduce those errors. Regardless of the sophistication of the device, the primary clinical goal of ATC interventions is to improve performance of functional activities that are critical components of independent community life, that contribute substantially to quality of life, or that significantly reduce caregiver burden.

In the World Health Organization's International Classification of Functioning, Disability and Health (ICF),[16] assistive technologies are considered to be an *environmental factor*. Other environmental factors are shown in Table 1. These include support from other persons, including the psychosocial factors of cultural and attitudinal influences on the part of those persons; accommodations to the built, physical, architectural space; and the characteristics of the available services available to persons with disabilities. Environmental factors can include access to healthcare and rehabilitation, access to AT and personal assistance, and access to

TABLE 1
ICF Environmental Factors

Products and technology: Any product, instrument, equipment, or technology adapted or specially designed for improving the functioning of a disabled person and to enable the ICF domain of activities.	
Natural environment and human-made changes to environment: Animate and inanimate elements of the natural or physical environment, and components of that environment that have been modified by people, as well as characteristics of human populations within that environment.	
Support and relationships: People or animals that provide practical physical or emotional support—nurturing, protection, assistance, and relationships—in the home or place of work, at school or at play, or in other aspects of daily activities.	
Attitudes: Attitudes that are the observable consequences of customs, practices, ideologies, values, norms, factual beliefs, and religious beliefs.	
Services, systems, and policies: Services that provide benefits, structured programs and operations in various sectors of society and are designed to meet the needs of individuals. (Included in services are the people who provide them.)	

information. Environmental factors are assumed to have downstream effects on the ICF domains of body functions, activities, and participation.

Accommodations in the built or natural environment, public areas, and work sites; appropriate health care; available personal assistance; and accessible forms of information are all key resources essential for persons with disabilities to participate in society and fulfill desired social roles. Additionally, for individuals having cognitive difficulties, barriers may be more subtle or not as readily appreciated by the community. For these individuals, limitations of the cognitive/informational components of the built environment may represent far more significant barriers to accessibility (eg, highway signs that are confusing or inconsistently color coded, store and marquee signs that don't clearly communicate the product being sold, insufficient maps and informational kiosks at large shopping malls). As noted in the discussion section below, growing recognition of these cognitive barriers will become increasingly important as persons with cognitive disabilities return to community life. Because assistive technology is intended to facilitate health and functioning, lack of resources to find or purchase AT constitutes an *environmental barrier*. A lack of trained personnel to assist in choosing and obtaining AT also constitutes a barrier within the social environment (as do policies that set a low priority on resource allocation for AT). The failure of a service provider to require that personnel conduct a comprehensive assessment of consumer needs and priorities, abilities related to the use of AT, and AT preferences at the beginning of the AT and support selection process is also a barrier.

IV. SPECIFIC AT DEVICES FOR COGNITIVE DISABILITY

Two broad areas of function with which individuals with cognitive disabilities often need assistance are memory and organization. A variety of techniques and devices have long been used for supporting these abilities, including "low-tech" devices such as written lists, notebooks, and planners. With training and rigorous practice and use, written strategies can help persons to remember daily tasks and routines more effectively.[17] For example, a randomized control trial showed that extensive, systematic group training in notetaking strategies resulted in fewer self-rated everyday memory failures, compared to a "sham" group therapy focused on general problem-solving abilities.[18] Although a variety of written strategies such as notebooks, planners, and lists are in widespread use in rehabilitation programs, training in how to use them is typically conducted with a less systematic approach than in a research protocol,[19,20] and this results in varied proficiency in and satisfaction with their use.

Despite their popularity as assistive devices, paper memory and organizational systems have certain drawbacks for those with cognitive disabilities. Paradoxically, the very deficits that a notebook is designed to remediate may make it hard for the user to implement the strategy, and there is evidence that training on written compensatory strategies is most effective for people whose cognitive impairments are not severe.[10,21] That is, it may require memory, executive function, and behavioral self-regulation to keep track of a notebook and to initiate its use at appropriate times[22]—all of which are typically challenging for those with more severe forms of cognitive disability. Users may learn to record appointments in a planner but still miss them by failing to consult the book in time. Thus, the person with cognitive disability may remain dependent on therapists and family members for continual reminders to "use your book." Recognizing this difficulty, Kirsch and colleagues[23] developed an intervention using a generic system similar to NeuroPage that provided cues for making entries in a standard memory book. The study participant, an individual with a history of both TBI and resected intracranial tumor, substantially increased his reliable use of a memory log in response to these cues.

Another drawback is that memory notebooks may also be too cumbersome for some work environments or other situations where space is at a premium. Partly because they tend to be obtrusive, paper reminder systems such as notebooks and clipboards are resisted by some consumers as stigmatizing.[24] Additionally, there are important life activities or treatment goals for which written strategies do not readily apply. These include, for example, recalling information that is processed during a conversation, or remembering to engage in a specific adaptive behavior that must be repeated throughout the day, often at unpredictable times. In a recent study by Hart and colleagues,[25] persons with cognitive disability due to TBI were asked what strategies they used to handle 10 everyday tasks requiring memory and organization and whether their strategies were successful. Strategies were analyzed by task, success rate, and type of approach (eg, internal or external; systematic or haphazard). Substantial differences appeared across tasks in the types of strategies that people found to be effective. For example, "remembering things to do" was reportedly a difficult task for many respondents. This task was found to be performed more successfully with an external versus internal strategy, whether systematic or not. Using a list in a planner book, or a list jotted on a scrap of paper, were both reported to be effective. However, for the task of "remembering things people tell you," success was relatively low regardless of strategy type, and *no* respondents reported using a systematic external strategy for this task. This result was consistent with previous findings suggesting that recall of important orally presented information is less amenable to pencil-and-paper compensatory strategy training than some other types of information, such as daily activities or to-do lists.[4]

As noted previously, alternatives to paper-based supports now exist in the form of a variety of technological supports. In the 1980s, when desktop computers entered widespread use, several research programs began to explore the potential uses of computers for people with cognitive disabilities. The work of Glisky, Schacter, and colleagues[26–28] showed that patients with severely impaired anterograde memory were capable of learning word processing and other computer skills via programmed instruction on a desktop computer, with gradually fading cues. In another early effort, Kirsch and colleagues[29] developed cueing software known as interactive task guidance (ITG). In one application, ITG software was installed on a desktop computer that was housed on a rolling cart and taken along a janitorial route. The program guided brain-injured employees through their janitorial work routines with greater success compared to traditional note-taking strategies.[30] Although this system was mobile, computers of the era were too large to be truly portable assistive devices. That is, they could not be carried with the person into a range of settings and applications. As computers have become small and portable, it has been possible to conceive of wearable "cognitive orthoses." Electronic devices such as personal digital assistants (PDAs), pocket-sized computers, software-driven paging systems, and programmable wristwatches are gaining clinical use in rehabilitation programs and have been studied in controlled investigations within the last few years. A series of studies has demonstrated that a programmable paging system called the NeuroPage can help persons with brain injury keep appointments and complete other prospective assignments more independently.[31–33] The NeuroPage is an alpha-numeric beeper that sends pre-programmed reminder messages at set times. Thus, using it requires minimal learning compared to "mainstream" devices such as hand-held PDAs.

In a recent study by Wade and Troy,[15] five persons with TBI were provided with mobile phones that notified them of tasks to accomplish at specific times during a 12-week trial. Subjects or their caregivers kept diaries before, during, and after this period to select target goals and gauge the success of the phone reminders. All subjects reportedly achieved 100% success with time-linked activities such as taking medications. In another study, also using five respondents who kept performance diaries at home, van den Broek and colleagues[34] trained the respondents to use portable voice organizers to record messages and reminders about household tasks to perform, in the user's own voice. Improvement in the target tasks was reported for each case. Similarly, Yasuda and coworkers[35] used a voice recorder to prompt persons with memory impairments to complete a variety of household tasks. Performance reportedly improved for five of the eight participants.

Portable electronic devices have also been used with success in populations with developmental cognitive disabilities. For example, a pocket PC with specialized scheduling software was shown to help persons with mental retardation perform vocational tasks, both more independently and in a more timely fashion.[36]

Most of the studies discussed above focused on providing automated alarms for time-linked tasks, such as taking medications or keeping therapy appointments. Hart and colleagues[37] wished to determine whether automated prompts could have more general effects on clinically relevant behaviors. They designed a brief within-subjects trial to determine whether use of an electronic device, in this case a voice organizer, could help 10 clients with TBI recall the treatment goals they discussed with therapists in case management sessions. Individualized therapy goals were randomly assigned to an intervention consisting of recording and automated playback on the organizer, or no intervention (which meant goals were emphasized in the case management session, but not recorded). After 1 week, recorded goals were recalled significantly better than unrecorded goals. There was also some indication that participants in the trial were more conscious of their recorded goals and more likely to follow through with them. Building on the work of Hart and colleagues,[37] Kirsch et al[38] reported an intervention for an individual with moderately severe TBI, whose primary behavior difficulty was marked verbosity. An intervention was designed using a PDA that delivered a message at fixed intervals, recorded in the participant's voice, that instructed him to be brief. As anticipated, the participant's average utterance length during 45-minute group sessions systematically decreased in response to cueing, although the number of utterances during the group did not.

Research that evaluates the *efficacy* of an AT method in the limited context of a trial is a necessary first step. However, demonstrating the *effectiveness* of an intervention method, including AT, requires evaluating the utility and impact of the method in the larger context of the user's "real life," and over a more protracted period of time. Research that has taken this broader perspective suggests that a set of key factors in the usability and effectiveness of AT is the extent to which it meets a user's personal needs and expectations and provides perceived value and benefit.[39,40] Moreover, although randomized controlled studies are important for establishing an evidence base for interventions, results at the group level have not yet illuminated the process of determining individualized needs for AT support.[7–9] Clinically, there is a need for new devices and other supports that are completely customizable with low cognitive, sensory and physical demands.[9,41–44] Different populations with cognitive disability (eg, developmental disability, TBI and stroke, and aging and dementia) may need very different kinds of supports due to differences in age, literacy, and familiarity with technology, as well as diverse psychological and psychosocial needs.[12,40]

These needs are beginning to be addressed as more cognitive assistive technologies become available. This increase in technology is driven in part by mainstream demand, because even people with typical cognitive abilities seek supports for dealing with increasingly complex scheduling and information-processing demands in the modern world. The increase in technology is also driven in part by an increased recognition of the needs of people with all forms of cognitive disability.[42]

V. ADVANTAGES OF ELECTRONIC ATC DEVICES

Taken together, the studies cited previously suggest that persons with cognitive and neurobehavioral changes, including memory and organizational deficits, can compensate for some of these difficulties by using portable electronic devices. It is notable that in many of these investigations, participants were chosen for the severity of their cognitive impairments and had failed in the use of traditional strategies. Below we discuss several specific advantages that may be found to accrue from the use of the newer, "high-tech" ATC.

A. Possibility of Lasting Benefit

For some persons, improvement on prospective memory tasks has been shown to persist after the devices are withdrawn, suggesting that the devices' repeated cues can become internalized.[32,33,35]

B. Portability

Devices such as hand-held computers and pagers are conveniently sized and able to travel everywhere with the user.

C. Consumer Acceptance

In one survey of people with acquired brain injury regarding everyday memory aids and their effectiveness, electronic strategies were rated as more effective overall than paper strategies.[45] However, only a small number of survey respondents in that study had ever used electronic aids. Recently, Hart et al.[25] surveyed 80 persons with moderate-to-severe TBI, most of whom were chronically disabled, regarding their interests and experiences with portable reminding technologies. Both interest in and comfort with new technologies were relatively high, suggesting general receptivity to technological solutions. The majority of participants said that they would like to use devices for everyday memory and organizational tasks, but this interest was not strongly related to perceived need for strategies, which was low overall. This suggests that persons with acquired brain injury might not initiate use of assistive electronic devices after injury but may be receptive to using them, if they are offered within a clinical program. Thus, compared to paper-and-pencil memory and organizational aids such as notebooks, portable electronics may be more acceptable, even desirable, to rehabilitation consumers.

D. Other Psychosocial Benefits

In addition to allowing users to accomplish tasks more independently and freeing up caregivers' time, authors have pointed to the potential for psychological benefit from the use of portable electronics[46–48] such as the social acceptability of being reminded by a device rather than another person, which could be perceived as nagging. For reasons of both effectiveness and acceptability, mastering the use of commercial technologies could serve to include, rather than stigmatize or exclude, disabled persons from the mainstream of society.[36]

VI. DISADVANTAGES AND REMAINING QUESTIONS ABOUT ELECTRONIC ATC

A. Efficacy Versus Effectiveness

As discussed above, efficacy studies do not necessarily speak to effectiveness in the real world. The studies to date have evaluated the efficacy of electronic ATC in limited clinical or experimental situations. Effectiveness of ATC implies on-going success, about which there remain many questions. Will persons with cognitive disabilities be able to troubleshoot technical problems that may accompany long-term use of electronic devices, such as battery failure? Will a caregiver be required to assume responsibility for on-going training and support? A demonstration of clinical effectiveness (as well as cost-effectiveness) may depend on the individual's ability to use the device without the technical assistance and close monitoring of others.

However, even for individuals who require some assistance for physical tasks (eg, recharging and replacing batteries) or maintenance tasks that cannot be easily automated (eg, hot-syncing a Palm-type device), the overall functional benefits to users and caregivers may far outweigh these relatively minor inconveniences. Another unresolved issue is that a clinically effective device would most likely be used for more than one purpose as a memory/organizational aid, whereas most of the research to date has focused on one, or a few, demonstrated activities.

B. Does Electronic ATC Work Better Than More Familiar Strategies?

Few studies to date have compared the efficacy of electronic ATC to other strategies more commonly used for prospective memory. Even if high-tech devices are shown to work for prospective memory tasks, how do we know whether they work better than diligently applied, lower-tech strategies?

A few investigations have addressed this question. One study of persons with Alzheimer's Disease found that electronic alarms acted as highly effective reminders, whereas a traditional written schedule of activities was no more effective than simply receiving verbal instructions to do things at specific times.[49] More research of this nature would help to establish which cognitive assistive devices work best compared to others, and for whom. Comparative interventions could also be structured in a variety of ways to help determine the "active ingredients" of using an electronic aid: Are the important variables the modality of output (eg, spoken vs. written), the automatic prompting function, the availability of interactive guidance, or some combination of these factors?

C. Can People with Cognitive Disabilities Manage Their Own Technology?

Persons with disabilities are often on the wrong side of a "digital divide," with less technology access and expertise than nondisabled persons.[50] Although cost is often cited as a barrier to procuring and using technology, cognitive as well as physical impairments may also make it very challenging to learn and use new technologies.[51] Cognitive limitations may be more salient than financial factors in affecting access to new technologies. As mentioned above, the alarm function on most devices may help remind users to initiate use of AT, but this advantage presupposes that someone has been able to figure out how to set the alarm. Commercial device interfaces may be difficult or impossible for persons with disabilities to use, requiring expensive custom programming.[52] Although research is needed to help determine what types and levels of ability are needed to learn and operate many types of assistive technology, and to evaluate how devices should be changed to accommodate users with cognitive as well as physical disabilities, high-tech ATC may present its own set of challenges. Previous authors[53] have speculated about client characteristics that may predict success with electronic devices among persons with brain injury, but these have not yet been tested systematically. A survey of clinicians working in TBI rehabilitation[54] revealed that learning and memory, fine motor skills/dexterity, motivation, attention skills, and insight into deficits were believed to be the most important foundation skills for achieving success with electronic ATC. It is somewhat paradoxical that respondents considered learning and memory to be a prime target area for remediation with devices, yet learning and memory were also considered necessary for successful use of high-tech ATC by nearly half the sample. Thus, when clinicians consider good candidates for this type of AT, it appears that persons with some basic level of learning skill who, nonetheless, need a compensatory memory strategy, and are aware of this need, are the best candidates. However, these are assumptions that need to be put to empirical test.

It is important to note that assistive technology devices and systems can be developed that accommodate some of these user-based limitations. For example, if a person has difficulty setting a PDA alarm, interventions might need to include alarms, or even entire schedules, that are set remotely and then transmitted to the user's device at appropriate times. This was the model used in the

1990s to develop the NeuroPage system.[31–33] Similar interventions, using devices with a greater range of features, may include pictures, voice commands, greater interaction between the user and the cueing system, including responses sent by the user to the system in response to cues or queries, and modifiability over time in response to user performance. For users whose cognitive characteristics serve as barriers to the successful operation of an electronic device, automated, quasi-intelligent, or remotely managed devices may be more beneficial than the off-the-shelf versions. For such individuals, "transparent" systems may even be helpful, in which behavior is monitored or cues and interventions presented in ways that do not appear to the person to be associated with a technological system. For example, for persons who are unable (or unwilling) to operate even a simple technological device, environmental sensors that note when an activity component has been performed (eg, opening the refrigerator) or a specific location has been entered (eg, the dining room), may be far more beneficial than requiring that a user generate a response. Similarly, systems that implicitly incorporate acquisition of a user response (eg, sensing that a piece of bread was put into the toaster), rather than requiring an independent confirmation of this activity (eg, by touching a device), may be most appropriate for persons who would be distracted if required to generate a response that is independent of the primary activity being performed.

VII. THE IMPORTANCE OF ASSESSING THE MATCH OF INDIVIDUAL AND DEVICE CHARACTERISTICS

Expanded choice in devices and features means differences among individual users can be accommodated. However, this also means that the process of matching person and technology can be more complex.[7,8] All aspects of a person's cognitive, physical, and sensory capabilities must be taken into account in recommending technology.[7,12,44] Features that are designed to address one impairment may negatively impact other aspects of the person's needs. A reminder system that is designed to be small and portable, so that a person with a memory impairment can easily carry it wherever he or she goes, may have such small controls and displays that a person with fine motor or visual impairments cannot use it. Similarly, a device that is highly customizable to a person's needs may be too complex for someone with a cognitive disability to learn how to use, unless the user interface is sufficiently simple.[44]

The complexity of matching a person and technology does not only arise from the individual's unique combination of physical, sensory, and cognitive abilities. In addition, people's expectations of and reactions to technologies are complex and highly individualized.[7] These reactions emerge from varying needs, abilities, preferences, and past experiences with and exposures to technologies. Predispositions to technology use also depend on one's temperament/personality, subjective quality of life/well-being, views of physical capabilities, expectations for future functioning, and financial and social/environmental support for technology use.[7,55,56] These factors and considerations have been organized into a model of influences predisposing individuals to varying degrees of technology and other support use.[7,9] The model has been operationalized by a series of assessment instruments[56] addressing the match of individual and device characteristics and the relevant environments most impacting a good match.

In the example of a high-tech ATC such as a portable electronic device, matching the individual and the device also means specifying the nature of the interface so that the user gets the right amount of support, yet is afforded the right amount of flexibility, to accomplish the desired task(s) within his/her cognitive capabilities. We expand upon this theme below in a discussion of programming high-tech devices as ATC.

VIII. CONSIDERATIONS FOR SELECTING TYPE OF USER INTERACTION WITH ELECTRONIC ATC

Three general approaches to electronic ATC intervention have been explored, each emphasizing different types of user interactions with devices.

1. "*Single message–static response*" systems are often based on devices such as pagers, telephones, or personal digital assistants. These

systems simplify interaction by restricting user responses to a single-button press (or functional equivalent such as a screen tap) in response to messages that provide cues about time-constrained tasks.[31,33,37] In effect, these devices are like sophisticated alarm clocks that can provide cues at preselected intervals.

2. "*Personal organizational systems*" provide an active method for users to enter, manage, and use information such as daily appointments, to-do lists, and financial records. Some of these systems (eg, PEAT,[57] Autominder[58]) are based on personal digital assistants but incorporate specialized software designed to facilitate use by individuals with cognitive disabilities. Other off-the-shelf systems offer software "suites" that include calendars, word processing, and money-management programs. The degree to which the user can use these applications depends on the system, the task to which it is applied, and the ability of the user. For example, a commercial PDA may be usable and useful for a person with mild cognitive impairments, or for someone who is moderately impaired who learns and uses only one of its functions by rote. However, comprehensive use of many PDA functions can be challenging, even for persons without cognitive disability. On the other hand, PEAT[57] or Autominder[58] use software routines that can manage fairly complex scheduling tasks that are not available on standard PDAs. From the user's perspective, the responses required to use the device may be indistinguishable from a single message-static response system because the "reasoning" necessary to manage daily schedules is handled by the software.
3. "*Interactive activity guidance*" requires a response from the user that provides the system with information about the status of a task (ie, the user's progress while performing the task) in order to make decisions about subsequent cues and alarms (Kirsch et al,[41] MAPS,[59] PocketCoach,[60] Jogger[61]). The distinguishing characteristic of these interventions is that they present message *sequences* that correspond to the stages of an activity, requiring users at each stage to provide input about task status or error conditions.

Because interaction is such a critical component of these interventions, early decisions must be made during the discussion of device selection about the interface that will best suit the user's needs and preferences. Interface features must be considered regarding the *device* or system that will be used, as well as the *task* that is to be performed using the device or system. The degree to which these two interface issues are related varies according to the particular intervention. For some interventions, a commercial device can be used without modification. For example, a person having mild impairments may require nothing more than a standard personal digital assistant to maintain daily appointments. However, for persons having more severe impairments, device simplification may be necessary because the standard device interface is too complex, too feature rich, or not sufficiently "intuitive." Additionally, in these cases, learning over time through practice and rehearsal may be required, even subsequent to modification.

Occasionally, device and task interface decisions are integrated, or at the very least, inform each other, particularly for specialized, user-specific, interventions. For example, Hiroshi Ishii has maintained a "Tangible Bits" research program at MIT that presents a unique approach to issues of ubiquitous, context-aware computing, and promotes the conceptual integration of device and task. In such systems, the user engages the computing system by engaging in the task, without having to consider, as a separate cognitive task, interacting with the computational system's interface. For example, Ishii and colleagues[62] developed a system to facilitate urban planning that presents the user with modeling components (eg, model houses, office buildings, roads). In performing the planning task (ie, moving and placing these tangible components to construct a model for an urban plan that incorporates features such as changing shadows, building reflections, and wind patterns), the user transparently engages the computational system without requiring that any additional interface features be manipulated. Other projects include toys that are able to learn movement after being manipulated (eg, blocks that, when constructed in the shape of a dog, will learn to walk after they are manipulated in a walking pattern)[63] or an art set that allows a child to point to and touch objects in a room with an electronic "brush," acquire the color of what was touched, and then paint with that color on an easel-sized screen.[64] Researchers at MIT have also presented data showing that memory cues presented through a wearable system in "real time" can be subliminal, in order not to divert the user's attention from the task at hand, and still enhance performance.[65] Although these developments have great potential for clinical applications, this level of integration cannot yet be achieved in rehabilitation settings. Typically, an intervention in a rehabilitation context will incorporate a *device* that is then applied to a *task*. The design of device interfaces and task interfaces are distinguishable operations and are worth contrasting. However, the above studies are noted because the goal of an effective ATC intervention may often be to develop a user interface that is as transparent as possible. This will particularly be the case for individuals having moderate to severe deficits, whose cognitive impairments limit the ability to interact effectively with a device.

A. Device Interface Design

Device interface design typically concerns itself with software and hardware features that are used to interact with the device or system. For example, designers may consider a number of features, such as the following:

- How many buttons can optimally be presented by a device (eg, fewer buttons minimize configural complexity but may increase procedural complexity by requiring that the same button be used for multiple purposes);
- whether the buttons are labeled with words (eg, "Min" and "Hour" buttons on an alarm clock or the "Talk" button on a cell phone) or icons (eg, application buttons on a PDA);
- whether alternative pathways are presented for achieving the same result (eg, being able to press a physical button on a PDA to launch the note pad, as well as tapping an icon in a folder);
- how many button presses or mouse clicks are required to "drill down" through menus in order to find needed features; and
- whether a specific interface feature can be hidden or "docked" when not needed (eg, an unobtrusive toolbar).

Device design requires attention to both physical and cognitive factors. For example, when developing a thumb keyboard for a PDA or two-way alphanumeric pager, designers may consider physical variables such as key size, spacing, and tactile responsiveness, based on information about modal user finger size, strength and dexterity. However, designers may also consider cognitive factors in order to improve efficient use of the keyboard. Along these lines, alternative virtual keyboards have been proposed that improve performance (after practice) by rearranging letter placement based on statistical analysis of letter digraph frequency (eg, in English, the digraph "t–h" occurs more frequently than "b–r" and both far more frequently than "n–u"). For virtual keyboards, which are used with one-handed tapping, for some users words per minute can be increased by arranging letters so as to decrease average interletter search time and stylus excursion distance.[66]

As an example of iterative device interface design, Kirsch, et al.[38] reported the development of an ATC intervention for management of verbosity after moderately severe TBI, with other complicating factors including a long history of alcohol abuse. The intervention that was eventually tested in the reported study presented a cue to the user, at 15-minute intervals, instructing him to "be brief." The cue was recorded in the user's own voice and presented by a Palm-type PDA through an earphone while the user was participating in group therapy sessions. The results of this study indicated that utterance length was reduced in response to intervention, as might be expected given the cue to "be brief," but utterance frequency was not reduced, suggesting a high level of response specificity. However, the intervention that was reported represented the last of several interventions that were each briefly negotiated and tried with this participant as part of an iterative design process. During earlier iterations, the cue was recorded in a therapist's voice but changed to the user's voice because he insisted he would be less likely to respond to a directive from another person. Similarly, another earlier intervention presented cues at a much briefer intercue interval, but the participant became frustrated with frequent interruptions, at one point angrily striking the touch screen of the PDA with a stylus. Lengthening the intercue interval eliminated this level of frustration. Frustration and potential embarrassment was also minimized by concealing the device in the participant's pocket and having him tap the screen with his finger, rather than with a stylus.

B. Task Interface Design

In contrast to device interface design, task interface design concerns itself with the activity for which an assistive device will be used. Since AT interventions are prescribed to facilitate performance of functional tasks, these tasks must be analyzed and assessed in much the same way that the device must be assessed. In our estimation, the most critical issues associated with task analysis and implementation are normative task difficulty and the user's level of cognitive impairment. The degree to which these two interface issues are related varies depending on the intervention. A person with mild cognitive impairments subsequent to traumatic brain injury (TBI) may require no modification other than the use of a PDA to manage information. However, for individuals whose cognitive functioning has been more significantly compromised, the task itself, including how a person interacts with the task, may have to be modified. For example, tasks can be simplified by reducing the number of steps, limiting the number or types of items to be used or manipulated, or by requiring that a task be completed without interruption (ie, controlling branching to other tasks or multitasking).

In clinical practice, task interface requirements will often be determined by the specific error patterns observed when the user performs a target activity. These errors are likely to represent an interaction between the user's cognitive profile, device features, and the cognitive demands of the task to be performed. Some cognitive difficulties are likely to be so pervasive that they will be expressed across many tasks, often regardless of content or difficulty. For example, a person with severe memory problems may have difficulty with the explicit acquisition of new information—an impairment that limits not only the performance of functional tasks, but, as noted above, the acquisition of the steps necessary to use a compensatory device. However, in many cases, the emerging error pattern will be characterized by seemingly idiosyncratic errors that are not evident when the person is performing other tasks. In either case, error patterns must be analyzed carefully in order to develop hypotheses about intervention features that promote a compensatory approach to the task.

The process of task simplification can be quite challenging. Users are subject to distraction, misunderstandings, interruptions, mood variation, fatigue, and many other factors that interfere with consistent performance. Additionally, the environment or context in which a task is to be performed may vary from day to day. Because of these variables, it will often be necessary to redesign an intervention, sometimes repeatedly, by changing task interface features so that these sources of variability are controlled and errors systematically minimized. However, this ideal cannot always be achieved. At some point in the design process, it may become evident that for an individual with very high variability in error patterns across trials, the level of task interface restrictions necessary to assure accurate performance may be far more restrictive than what is reasonable, given the goal of achieving assisted independence for the task, and interventions other than ATC may be necessary.

As an example of iterative task interface design, Kirsch et al[41] presented the case of an elderly woman with severe cognitive impairments (subsequent to TBI against a backdrop of probable progressive cognitive decline) who had difficulty setting her alarm clock. The study reports an intervention using pictures of the participant's alarm clock presented interactively on wireless enabled laptop computer, with instructions about how to complete the task.

During clinical assessment, the severity of the participant's cognitive impairments had been well established. However, it would not have been possible to predict the specific and sometimes surprising errors she made when attempting to complete the task independently (ie, without AT guidance). In one instance, she had difficulty comprehending the text "Hour" and "Min" under associated alarm clock buttons. A variety of cue modifications were attempted to improve performance, but all were unsuccessful until the buttons, with associated visual cues, were color coded. In another instance, the participant perseveratively maintained pressure on one of the clock buttons, thereby scrolling the digital display beyond the correct alarm time. Several alternative cues were also attempted to correct this error, but all were unsuccessful until explicit directions to release the button were included in the cue set. To achieve device and task interface presentations that substantially reduced errors, multiple iterations of the ATC intervention were required until the perceptual elements of the clock and sequential elements of the task had been changed enough so that error incidence was reduced to acceptable levels.

In our experience, for many ATC interventions, iterative changes like these will be necessary. The first "pass" intervention, and perhaps the third or fourth, may not adequately promote acceptable target activity performance, either because an error that occurred during an earlier design iteration was not successfully eliminated or because new errors emerge in response to intervention changes that had not previously occurred. For this reason, as will be noted in the "Rehabilitation Team" section below, it is critical that any ATC intervention, even those using "off the shelf" devices or systems, be developed with a full understanding of the user's clinical status, including stimuli and environmental circumstances that are likely to either minimize or exacerbate behaviors that result in error.

Our clinical experience suggests that as symptom severity increases, direct modifications to the task interface become increasingly important. These modifications are often preemptive, in that they guard the user against errors by offering alternative ways of performing a task that take the user's cognitive characteristics into account. Such a strategy not only improves performance but may enhance learning over time, even for persons with severe memory impairment, through errorless learning. This form of learning, contrasted with "trial-and-error," appears to benefit those with severe explicit memory deficits by capitalizing on the residual implicit memory system.[67.68]

However, it should also be noted that every potential user may not benefit from an ATC approach (just as every rehabilitation therapy consumer will not benefit from any one single intervention). In particular, this will be the case for users whose cognitive and behavioral presentation is characterized by unpredictable error variability across learning sessions (attributable, say, to a specific pattern of cognitive impairments or a particular level of impairment severity), or users for whom the best comprehensive efforts to match them with appropriate technology is simply not successful.

IX. THE IMPORTANCE OF SKILLED AND KNOWLEDGEABLE PROVIDERS

Another element of the *environment* that is key to an individual obtaining the most personally appropriate device is the availability of trained and skilled AT providers who are knowledgeable about assessing consumer needs and preferences, devices, interface options, etc., and who are able to provide the most appropriate services. In addition to defining assistive technology devices, the Tech Act of 1988 defined assistive technology service, as follows:

> Any service that directly assists an individual with a disability in the selection, acquisition, or use of an assistive technology device, including...evaluation of the needs of an individual...; Purchasing, leasing, or otherwise providing for the acquisition by an individual with a disability of an assistive technology device; Selecting, designing, fitting, customizing, adapting, applying, maintaining, repairing, or replacing assistive technology devices; ...Training and technical assistance...

The communication problems and difficulty with memory, reasoning, and problem solving experienced by many people with cognitive disabilities requires skilled professionals trained to help consumers identify and understand their strengths as well as limitations, evaluate whether self-perceptions of strengths and limitations are realistic, and facilitate the expression of desired goals, preferences, and expected technology benefits. Clinician attitudes and expectations are important for selecting, training, and supporting the use of any assistive technology—high- or low-tech—and may strongly affect the acceptance and use of devices by clients.[70] Clinician knowledge is one of the key factors that determines whether consumers are appropriately matched to assistive technology,[69] and ongoing training and support from professionals is considered vital to the success of compensatory devices.[70]

Clinicians involved in rehabilitation routinely, even casually, experiment with their clients using low-tech assistive devices, such as paper-and-pencil systems, for enhancing memory and organization. However, clinical experimentation using high-tech strategies is much more infrequent and difficult and carries higher stakes, partly resulting from the costs of emerging technology.[70–72] Clinicians may also be reluctant to experiment with emerging technologies due to lack of knowledge or low confidence in their ability to keep up with rapid technological changes. For example, in the clinician survey cited above, about half of the respondents had already been exposed to clients who used or attempted to use commercially available portable electronic devices. However, relatively few expressed confidence in their ability to train or support clients in the use of such technology.[54] Thus, many professionals want to be, and realize they need to be, more consumer responsive but have not received the training they need in how to efficiently and effectively accomplish this.[73–74]

X. ATC AND THE REHABILITATION TEAM

The increasingly important role of ATC in the rehabilitation of persons with cognitive impairment has been recognized by many in the field of physical medicine and rehabilitation. However, the challenge as to how to most successfully offer, provide and support the use of AT with rehabilitation populations has not been met.

Considerations for the rehabilitation team can be encapsulated by the "5 w's and h":

- Why? Determining what the ATC needs to do for the user.
- Who? Multidisciplinary and coordinated approach.
- When? Repeated assessment of ATC needs.
- Where? Home or community evaluation of ATC use.
- What? Incorporating training of ATC in rehabilitation.
- Follow-up and support for ATC.
- How? Training rehabilitation professionals on ATC

Why? Determining what the AT needs to do for the user. No single person on the rehabilitation team can be expected to know every available resource and device that might be appropriate for use as an AT persons with cognitive disability. Specialized expertise usually exists in the facility or community on the part of rehabilitation engineers, occupational therapists, neuropsychologists, and so on. But any member of the rehabilitation team can and should listen to and observe the potential user in order to understand that person's strengths, weaknesses, preferences, and goals. When these are discussed among the team members, a comprehensive picture of the need, followed by strategies and potential supports, can be better developed.

Who? Multidisciplinary and coordinated approach. Part of the challenge of the successful application of ATC for persons with cognitive impairments may be securing the multidisciplinary approach that appears to be an essential component for providing ATC to patients and families. In fact, a review of the literature demonstrates that ATC research has been tackled by a variety of rehabilitation professionals, including occupational therapists, physical therapists, rehabilitation engineers, physiatrists, and psychologists. Although these professionals are typically not formally trained in technological development or application, and as such may not have the expertise to fully include every possible factor (such as usability and ergonomic adaptations), a multidisciplinary approach and good communication among the various team members is what is most important for providing the necessary considerations for the successful integration of ATC. An effective multidisciplinary team implementation of an ATC program should, thus, have individuals who represent such skills as clinical assessment and intervention, knowledge of what is and isn't available, knowledge of what specialized interventions are possible, knowledge about the devices, knowledge about assessment, and so on. In other words, the effective team includes a comprehensive skill set, perhaps augmented with consultation.

When? Assessment of ATC needs. In a recent study examining the use of assistive devices in stroke survivors, researchers reported that initial needs (at discharge) for assistive devices were predominantly aids for mobility and physical assistance. However, at a 3- to 5-year follow-up, there was a significant increase in the need for assistive devices for cooking/eating and reading/hearing/writing.[75] These findings may suggest that the initial evaluation of ATC needs may be focused on physical needs, but the cognitive needs, which typically impact activities of daily living, may not be identified early on. This point may be particularly salient for individuals with cognitive impairment who also have physical impairments, such as stroke or multiple sclerosis.

Similarly, there has been some evidence that indicates that the highest prescription for AT occurs early in the acute rehabilitation phase.[76] If ATC is not considered early enough, and cognitive issues are addressed in the acute phase, individuals may not receive the appropriate supports. On the other hand, some cognitive impairments may become apparent only postacute rehabilitation or upon the return to home. This indicates the value of an additional or secondary evaluation of ATC needs by a rehabilitation specialist post acute rehabilitation, as well as an evaluation early in rehabilitation.

Where? Home or community evaluation of ATC use. Given the diversity of environments where ATC devices may be used, consideration of where training and evaluation is conducted should be addressed by the rehabilitation team. Although a majority of evaluations are conducted in the clinic or hospital, home evaluations may offer a unique opportunity for evaluating the interface between the user and the ATC device in a more natural setting and provide a chance to address unforeseen problems. Similarly, vocational rehabilitation professionals, working in conjunction with the rehabilitation team, may also take advantage of on-the-job training to evaluate the use and integration of the ATC device in work settings. The generalization of ATC use to functional community settings is critical, but assessment in the clinic is necessary as a first step to see if the ATC intervention is even reasonable and a good match with the user. Early prescription provides the basis for making initial decisions, whereas ongoing re-evaluation, modification, and incorporation into home/community settings promotes generalization and sustained use.

What? Incorporating training of ATC in rehabilitation and follow-up and support for ATC. As previously discussed, an essential component of a comprehensive evaluation includes the individual's physical, psychological/emotional, behavioral, and cognitive skills; an analysis of the features and demands of the technology on the user; and the physical and psychosocial aspects of the environment most apt to influence the device's use. It is then essential that the user receive training in how to optimally use the device, as well as any maintenance requirements (eg, recharging batteries). Once the individual receives training, then ongoing support for use, upgrades in device features, and accommodations to the user's changing capabilities will need to be made.

However, even issues of training may be influenced by a variety of factors. For some individuals, one-time training in the use of an electronic device or system may be all that is necessary. This may be the case because their cognitive changes are mild or because the device interface is truly intuitive. However, for users having far more severe cognitive changes, assistive technology may still be useful, but use may need to be transparent to the user. For those with very severe cognitive involvement, they may benefit primarily from an ATC system's interaction with the environment (eg, turning off the stove automatically if it's been left on to long; placing a call to a caretaker if difficulties arise) without the user even being aware that these interventions have occurred. In our opinion, the critical issue regarding the identification and prescription of ATC is that the multidisciplinary team be fully apprised of available systems, how these systems operate, the range of applications to which the system features can be applied, and the user's clinical status, so that the prescribed system matches the user's training (and other) capabilities. Having noted this, it may be the case that caregivers, rather than the target user, may be the focus of training. This is also a critical responsibility of the team, particularly if the ATC system will be used in a home or residential treatment context, without the benefit of daily intervention from the members of the prescribing team

How? Training rehabilitation professionals. One method of training rehabilitation professionals on providing AT services is the use of online or Internet-based education. Although many of these have not specifically focused on ATC, many of the benefits offered through this training are applicable, such as (1) providing education on key issues associated with ATC (usability, technology-user matching and ergonomics, and so on); (2) increasing awareness about the various types of ATC that may be available for the different types of impairments; and (3) providing access to resources and expertise. Recent studies examining the efficacy of this approach for general AT have served to demonstrate its usefulness in training practicing rehabilitation professionals.[77]

Individual characteristics of the therapist and of the therapist/patient relationship have been examined as they relate to the use of AT. There is some evidence that the greater the degree of involvement by the therapist, the more likely the AT will be used and the more optimal its usefulness.[78] This may be a factor of "getting to know the patient and his or her needs" and, subsequently, being able to identify the appropriate AT matches for the individual. Greater therapist involvement may also specify the type of involvement the therapist should have with the individual and help identify and recommend additional services that may be needed to ensure the successful use of the AT by the individual. Finally, the benefit of a multiple therapist and multidisciplinary approach can also be considered here. For example, although psychologists may have a good understanding of an individual's cognitive impairments, they may not have the opportunity to be involved with the individual during more functional everyday activities, as do occupational therapists. As such, an individual recommendation from one therapist may not cover all of the key elements for matching the person with the ATC device. However, a combined evaluation and recommendation from both the psychologist and occupational therapist may be a better solution for identifying the individual's ATC needs.

XI. ASSESSING OUTCOMES OF THE AT INTERVENTION

Although there are many devices appropriate for use by persons with cognitive disabilities, today about 90% of AT for cognitive compensation is discarded after only brief use.[73] Psychosocial factors appear to underlie many instances of device nonuse, partial, and inappropriate use. For example, users who do not believe that they are involved in the selection of their assistive technology devices are more likely to discontinue using them than individuals who feel involved.[7] It has been argued that people may discontinue using devices because their personal expectations of performance, or the expectations of their caregivers, following disability onset may be reduced dramatically.[7] This leaves open the matter of psychosocial factors not being adequately assessed, explored, and attended to before devices, which are often complex and expensive, are delivered.

The AT literature includes some good nonexperimental (survey) research on what forms of AT are discontinued and how often, but it has not addressed persons with TBI. It is not clear, for example, whether users in some instances have stopped using a device because of changes in their life circumstances that have nothing to do with how well the device is designed, how well it performs, or how satisfied the user is with its performance and usefulness. Other possible factors associated with nonuse include unrealistic expectations, inappropriate needs assessment, poor device selection, lack of support from caregivers, and any combination of these.[74]

It is likely that a major overarching reason for discarding AT is that a device is not typically evaluated in the context of the whole person and his or her environment, despite the fact that this is in keeping with the World Health Organization's International Classification of Functioning, Disability and Health. Factors influencing sustained use that should be evaluated in the context of that use include the following: (1) The appropriateness of specific device features (eg, is there a keyboard?; how big are the keys?; is the screen readily visible?; are there too many buttons?); (2) changing characteristics of the patient (eg, progressive memory decline; decreased motivation associated with depression); (3) changing patterns of functional demands over time, such as changing demands at home or at work (which may render technologies obsolete that were prescribed at an earlier time); and (4) psychosocial/interpersonal variables, such as the degree to which a person receives support for AT use from others or the degree to which a particular device is viewed by the person as stigmatizing.[7] Since AT interventions can be relatively expensive, further research on the factors that contribute either to nonuse or poor generalization across functional settings will be very important.

For many rehabilitation interventions, the first assessment "pass" must consider the immediate impact of the intervention within a clinical setting (ie, "does *this* intervention actually promote a change in *that* behavior?"). This first "pass" determines whether it will even make sense for a clinical team to pursue further development of a specific intervention, including whether efforts should be made to incorporate the intervention in the broader contexts of a user's life. However, once effectiveness in the clinic has been established, a second, and perhaps far more critical, "pass" requires appreciation of the many complex factors that are likely to affect sustained use of an intervention or the generalizability of the intervention across functional contexts.

Regarding the first level of assessment, a variety of approaches can be adopted. Most typically, AT interventions will be considered for specific individuals facing specific problems. Therefore, single case methodologies will often be required to assess the impact of an AT intervention. Many examples of this approach to assessment have been previously reviewed. These studies, as a group, suggest that AT interventions can be used effectively to facilitate performance of functional tasks that would otherwise require the AT user to rely on supervision or guidance from another person. However, as with all single-case designs, even those using multiple baselines across persons or tasks, generalizability will be restricted by the specific constraints of the study, including the target behavior, modifications to the design interface required by the unique pattern of errors encountered by the user during task completion, and the nature of the supporting context in which the assessment study was conducted (eg, familiar vs. unfamiliar, relatively controlled clinical setting vs. relatively uncontrolled community setting, a single behavior repeatedly performed in a single setting vs. a single behavior that is performed across multiple settings—all of which require a behavior of that sort).

These types of assessments will often be required, even if interventions are being considered that are based on a device developed for use by multiple people (ie, a commercial product). For example, it has by now been well established that alphanumeric paging systems can provide functionally significant support for persons with cognitive impairments by providing cueing about prospective tasks.[21,31–33,48] However, even for such devices, individualized assessment will often be important to establish various factors influencing clinical outcome for a specific user, such as

- mood, motivation for technology use, support for use, self esteem[56];
- device ease of use, range of tasks for which the device is effective, response consistency over time, whether different cue characteristics are needed by different users at different times or during different activities; and
- contextual barriers, such as environmental noise, and the degree of support from others for use.[7]

XII. CONCLUSIONS

This article has reviewed some recent work on the use of ATC in rehabilitation programs, some central issues of importance in the design of such interventions, and the importance of a multidisciplinary approach to ATC design and assessment. In summary, there are a number of critical issues that are important to emphasize.

First, assistive technologies for cognition, like the broader class of assistive technologies to which they belong, are most effective when they are shaped to meet and enhance a consumer's particular functional, personal, and social needs, not when they are prescribed as an isolated means of addressing a specific cognitive limitation. Technologies that do not fit with consumer preferences or preferred/customary ways of doing things have a decreased probability of use. Similarly, in our experience, technologies that address a component skill but do not demonstrate to users and caregivers that functional improvement will be forthcoming, are also likely to be abandoned. The question today is no longer whether or not to incorporate technology into rehabilitation, but which devices and product features will best address the functional needs and preferences of a particular individual with a cognitive disability.

Second, it is crucial that the process of matching the most appropriate ATC to individuals with cognitive disabilities involves a rehabilitation team. There are a number of reasons why we stress this point. The most critical is that ATC interventions, in our experience, are most successful when they are part of a comprehensive evaluation and treatment plan. The diverse areas of clinical expertise represented on the treatment team are all necessary in order to identify an appropriate problem area, experiment with nontechnological interventions that can then be implemented with ATC, and develop a method for assessing outcome within the context of a functional activity. Clearly, both clinical and technological skills are necessary to develop devices and systems that will work for cognitive disability.

Third, it is also critical that the process of ATC development and intervention not end in the clinic or after a few weeks, but continues over time and in the real world. Success with ATC will likely depend upon on-going, repetitive training in the use of the device, modifications based on formal assessment, and the availability of upgrades as the user gains proficiency and makes progress in rehabilitation. In the world of web design, this is known as iterative design. We believe strongly that this iterative approach is critical to successful intervention design and also fits well into a framework of systematic single-case studies for the individualized evaluation of treatment efficacy.[79]

Fourth, when enabling a person to perform desired tasks, it is possible that assistive technologies may provide a sense of competence and reconnection to the community. By accommodating a person's weaknesses and supporting his or her strengths, assistive technologies can reduce psychosocial stressors, thus leading to renewed confidence and self-esteem. We believe that this is a critical area of continuing research, since it may be the case that the renewed confidence associated with ATC use will, for some users, result in improved functioning in other domains for which ATC was not even considered.

Fifth, as individuals with cognitive changes make the transition back to community life, it is certain that they will encounter difficulties that are associated with how cognitive information is presented in the environment. The approaches to ATC interventions that we have reviewed in this article typically address the needs of an individual who is having difficulty with some type of task or behavior and is expected to benefit from external organization or cueing. However, these interventions cannot facilitate improved functioning if the person's cognitive environment is confusing or unintentionally husbands critical information. Just as consumers and rehabilitation professionals advocate for physical accessibility in the community, it is important to advocate for cognitive accessibility. Much of the information derived from ATC studies may have a direct bearing on recommendations for cognitively accessible community design, including how information is presented (eg, signage, menus, voice mail messaging systems with multiple menu levels, application forms) or even whether information is made available more readily and accessibly (eg, information kiosks). In some respects, the community itself can be construed as a "user interface." We believe that information derived from studies investigating ATC design and implementation will be critical to the design of communities that facilitate the full inclusion of individuals with nonmodal cognitive abilities.

As the individual cognitively improves or deteriorates, there will also be a need to revisit consumer goals and device appropriateness. For these and many other reasons, outcome assessment is a critical component of AT development and selection. Thus, the consideration of AT involves a cycle of consideration from appropriate device evaluation and selection, use in natural environments, upgrading and accommodating users' changing needs and preferences, and the provision of follow-up and follow-along support for use.

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