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Effectiveness of the ISAAC cognitive prosthetic system for improving rehabilitation outcomes with neurofunctional impairment

Patrick Gorman[a,*], Randy Dayle[b], Carrie-Ann Hood[c] and Linda Rumrell[d]
[a]*Independent Practice, Winter Park, FL, USA*
[b]*Cogent Systems, Inc., Orlando, FL, USA*
[c]*Florida Institute of Technology, Melbourne, FL, USA*
[d]*Winter Haven Hospital, Winter Haven, FL, USA*

Abstract. Cognitive rehabilitation has the capacity to empower persons with brain-injuries and help them achieve heightened functional, personal, and social interactions within their environments. Interventions aimed at compensation for deficits and adaptation to cognitive disability can be aided through the use of assistive technology devices (ATD's). ATDs allow for their users to experience greater levels of independence, as well as social and vocational participation, which leads to a higher quality of life. The ISAAC system is a small, individualized, wearable cognitive prosthetic assistive technology system. Being fully individualized and very easy to use makes this system adaptable to, and appropriate for, patients with a wide variety of cognitive disabilities ranging from individuals with developmental disabilities to high functioning survivors of brain injury. The current article will discuss two cases that illustrate the effectiveness of the ISAAC system in assisting patients with generalization of rehabilitation to their home environments. Both patients incurred significant cognitive impairment, for which they were able to successfully compensate with the assistance of their ISAAC systems. These two case studies are typical examples of the functional independence that can be achieved through the use of the ISAAC system. When patients are properly selected for use of this system, appropriate content is authored, and sufficient training on the system is provided, the ISAAC system can prove very effective at improving patients' functional independence.

Keywords: Brain injury, cognitive rehabilitation, assistive technology devices, cognitive prosthetic devices

1. Introduction

The consequences of brain injury resulting from multitudinous origins, (such as closed head injury, cerebrovascular accidents, and anoxia), can produce deficits across several domains of functioning, including physical, emotional, cognitive, and behavioral. In particular, impairment in the realm of cognition is the cause of significant disability in the lives of those suffering from brain injury [3]. The sequelae of these disabilities also negatively impact psychological functioning, exacerbating emotional and behavioral symptoms that are the direct result of brain injury. Examples of disabilities that stem from cognitive impairment include memory dysfunction, reduced efficiency, pace and persistence of functioning, decreased effectiveness in activities of daily living, and failure to adapt to novel or problematic situations [3]. In order to remediate and compensate for cognitive disability, and therefore enhance self-sufficiency and the quality of life of brain injured patients, cognitive rehabilitation services are administered. Cognitive rehabilitation refers to therapeutic service delivery, which focuses on functional brain-behavior relationships, over several domains of

*Address for correspondence: Patrick W. Gorman, Psy.D., ABPP, 1870 Aloma Avenue, Suite 280, Winter Park, FL 32789, USA. Tel.: +1 407 644 7792; Fax: +1 407 644 3509 E-mail: pgormanpsyd@earthlink.net.

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cognition, including attention, executive functioning, memory, visuospatial functioning, and problem solving. Interventions include those which reinstate previously learned behavior and compensation strategies for deficient areas, in addition to teaching patients how to adapt to their disability [3]. Therefore, these interventions have the capacity to empower patients with brain-injuries and help them achieve heightened functional, personal, and social interactions within their environments.

2. The role of assistive technology

Interventions aimed at compensation for deficits and adaptation to cognitive disability can be aided through the use of assistive technology devices (ATD's). In the broadest sense, ATD's are any tools that allow persons with disabilities to attain goals and maximize functioning [1,2]. More specifically, ATD's both enhance strengths in order to counterbalance the effects of the person's disability and provide alternative ways to perform tasks, thus promoting disability compensation [9]. ATD's allow for their users to experience greater levels of independence, as well as social and vocational participation, which leads to a higher quality of life. Furthermore, the utilization of ATD's serve to increase self-esteem and the self-confidence of persons with disabilities. The positive impact of ATD's extends beyond the patients themselves, in that persons with disabilities using ATD's are much less dependent on caregivers, which considerably aids in their psychological well-being, and quality of life [1]. The significance of ATD's in the lives of persons with disabilities is demonstrated through legislation, which mandates that rehabilitation agencies consider their use, and that educators and employers accommodate students and employees with ATD's [6].

Assistive technology devices that are specific to brain injury include mobility systems, communication systems, computers, toys and games, and finally, activities of daily living devices, such as watch alarms and memory books. An important facet in the remediation of cognitive disorders is generalizing rehabilitation strategies learned in therapy to non-clinical settings [10]. That is, patients who perform well in the clinic after rehabilitation often have a difficult time translating those skills to their everyday lives. The difficult, yet necessary task of generalization can be accomplished through the use of ATD's. Advancements in microtechnology and wireless communication have lead to the development of ATD's that aid in compensation for cognitive deficits, in particular, memory and executive (planning) impairments.

Examples of technological developments that aid in cognitive remediation include products such as the NeuroPage, the Voice It Personal Note Recorder, the Voice Organizer, palmtop computers, Essential Steps software for use on personal computers, and the ISAAC cognitive prosthetic assistive technology system. The NeuroPage is a system that programs reminder messages via computer, which are then sent to a pager that is carried by the patient. It has controls, which are deemed to be simple to use by its creators, as well as a voice based receiver option. Reviewers of the NeuroPage have noted that the device increases patient independence and self-reliance, as well as treatment compliance, leading to decreased treatment utilization [10]. In a study involving 20 subjects and utilizing an ABA design, Wilson, Evans, Emslie, and Malinek [14] found that all subjects benefited from the NeuroPage in the treatment phase. The authors of this article concluded that NeuroPage enhances independence and employability. Moreover, patients using NeuroPage experienced a relief from stress. The authors elaborated on the success stories of NeuroPage users, describing a subject who was able to return to college, and another that was able to return to work. In addition, one subject's wife was able to return to work [14]. Currently, a large study involving 200 participants is being conducted to further empirically evaluate the effectiveness of NeuroPage [13]. Disadvantages of this system are its high total life-cycle cost, its unsuitability for delivering complex or lengthy procedural guidance, and its inability to provide the patient a means to access supports as needed in response to many unplanned circumstances that are routinely encountered in daily life.

Other electronic devices are available and have been shown to be helpful in the rehabilitation of persons with cognitive disabilities. These devices are commercially available and not designed specifically for persons with disabilities. The Voice It Personal Note Recorder allows patients to record and playback messages and reminders. Its inexpensive price makes it an attractive option for many rehabilitation patients. Similarly, the Voice Organizer is a palm-size recording and appointment storage device using voice messages, which can be recalled through voice activation [10].

Another electronic option available is palmtop computers. Patients, to improve their time management, can use scheduling software that can be loaded into palmtop computers. A study examining the utility of

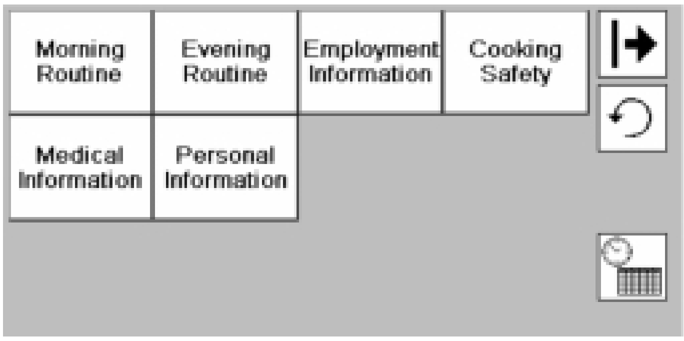

Fig. 1.

such devices was conducted involving 12 patients [7]. Results of this study demonstrated that 75 percent of these subjects reported that the palmtop computers had been useful to them on a daily basis. Furthermore, 58.3 percent of them reported that they planned to continue use of the device. Overall, the study concluded that the palmtop devices could allow patients with relatively minor degrees of cognitive impairment to achieve a higher level of autonomy and confidence. The researchers also concluded the use of the palmtop computer by the study's subjects contributed to a reduction in anxiety, which was thought to secondarily increase their self-esteem and life estimation. The device was evidenced to aid in memory functions, as well as frontal executive functions, in that it allowed for the maintenance of an active goal state. Similarly, the Essential Steps system provided comprehensive support for higher functioning skills, including personal finances, and organization and planning [2].

Each of these approaches can be effective for a certain group of patients and circumstances. However, such devices have significant shortcomings that reduce their appropriateness and effectiveness for many patients, especially those with more severe cognitive impairment. One shortcoming is their unsuitability for delivering complex or lengthy procedural guidance. Recording devices can typically accommodate only a relatively small number of simple information elements. With palmtop computers, a significant shortcoming is the means by which the patient must locate needed information. This procedure typically involves multiple steps, which are usually a series of taps on very small, specific locations on the device screen. It is also necessary for the patient to remember what information is stored in the system, where it is located within the storage scheme of the device, and the sequential procedure for navigating to and accessing it. The combination of these factors makes it difficult for many persons without disabilities to use such devices effectively and reliably, and virtually impossible for patients with measurable memory and/or executive impairment to do so. Another significant shortcoming is that while they are small, such devices must be removed from the pocket, belt clip, or other location where they are carried, and then hand held for use. This requirement makes them extremely vulnerable to loss and drop damage. It may also reduce their effectiveness for many environments and situations in which it is not practical for the patient to devote both hands to holding and manipulating the ATD. Another fundamental shortcoming of many of these devices is that they do not prevent accidental deletion or corruption of essential compensatory elements by the patient. Obviously, this can severely reduce the long-term reliability and effectiveness of the ATD.

In order for cognitive assistive devices to be effective, several considerations must be adequately addressed. It is imperative that rehabilitation specialists assure that patients have the requisite cognitive abilities to effectively and reliably use, and thereby gain practical benefit from the given ATD under consideration. For most devices, those criteria must include average or near average intelligence, normal to mildly impaired reasoning abilities, insight into deficits, and mobility to initiate activities. In addition, impairments in vision or in fine motor coordination may inhibit use of microcomputer devices such as those described. When explaining how to use such devices, rehabilitation specialists must simplify instructions and provide adequate teaching and modeling of technology usage [7,8]. Finally, when deciding whether to utilize such devices, factors such as cost, and appropriateness for consumer personality style must be considered.

3. The ISAAC cognitive prosthetic assistive technology system

An ATD that addresses the shortcomings of the other approaches described, and has proven very promising, is the ISAAC system. The ISAAC system is a small, individualized, wearable cognitive prosthetic assistive technology system. Fully individualized and very easy to use, this system is adaptable to, and appropriate for, patients with a wide variety of cognitive disabilities ranging from persons with developmental disabilities to high functioning survivors of brain injury.

As argued by Albert Cook [4], the ISAAC system was designed according to the Principles of Universal Design [12]. First it was designed to be useful and marketable to people with varied abilities, with flexibility to accommodate diverse needs. The ISAAC system design makes it very easy to understand and use for even persons with significant disabilities. Having the capability for both auditory and visual output increases the ISAAC system's usability. Additionally, the ISAAC system possesses a great tolerance for error, it requires low physical effort to operate, and it is well-sized to provide the maximal amount of content and screen readability in a device that is completely portable and wearable.

The system is battery powered and wearable, so the patient can have access to fully individualized prompting and procedural content in almost all environments and throughout the day. This portability makes the system a practical vehicle for providing necessary supports for patients in either independent or supported living situations, including employment.

The ISAAC system device is based on mainstream, state-of-the-art electronics and battery technologies, thus delivering impressive performance and capabilities at a relatively low cost. The system case and carrier were specifically designed so that the system will be accessible throughout the patient's daily life. The system device is large enough for the touch screen to be easy to use, while still being compact enough to be used while being worn. When folded to its closed position, it is about the size of many popular "fanny packs." The system is powered by long life rechargeable batteries that reliably last all day and are recharged overnight while the patient sleeps. The batteries remain contained within the ISAAC system case at all times, even during recharging, and are never removed by the patient. Additionally, battery technology employed does not suffer "memory-effect" and with normal daily use of the system have an expected life of two years or more before requiring replacement.

The system software on the ISAAC device enables the presentation of the patient's individualized prompting and procedural content. It also enables the patient, by means of "virtual buttons" created on the system touch screen, to easily access the desired content and features when they are needed in response to situations encountered in daily life.

There are two basic ISAAC system content types. One is system-initiated prompting, which is delivered to the patient as synthesized speech audio in either English or Spanish to initiate a behavior. Each system-initiated prompt is defined based on a specific condition, such as the day of the week and time of day, the time interval from a specified patient interaction with the system, the sequence of prior patient interactions with the system, etc. Most types of system-initiated prompts require positive acknowledgment from the patient by means of the touch screen, otherwise they are repeated every few minutes until they are acknowledged or superceded by another prompt that has become more appropriate based on the conditions specified. System-initiated prompts are useful for a wide range of purposes. One purpose is providing basic structure to the patient's day (prompting key activities from first thing in the morning to the last thing before bed at night). System-initiated prompts also can support employment performance (e.g., detecting off task behavior and delivering a corrective prompt), and implementing quality measures (e.g., detecting out of sequence performance of procedural elements and delivering a corrective prompt).

The other basic type of content is information that is accessed directly by the patient whenever needed or desired. This patient-initiated content may be procedural information for tasks or simply information that the user needs to access periodically, such as directions to locations, and can be presented in English or Spanish. The patient accesses this type of content by navigating to it, whenever it is needed, using the virtual buttons on the system touch screen.

The virtual buttons can be labeled with either text (in English or Spanish) or graphics. Since they are always visible, the labels provide constant reminders of what information is accessible. Therefore, the patient does not need to remember specifically what is available, where it is located, or what keyword is required to access it. The virtual buttons are organized hierarchically into "threads" of content, from general to specific, providing an intuitive path to the content the patient wishes

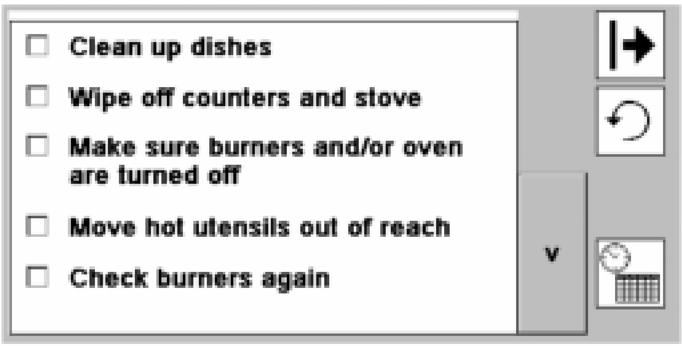

Fig. 2.

to access. For the basic format, which allows up to 12 virtual buttons displayed on each level of the hierarchy, each virtual button measures approximately 2.8 cm in width a 2.1 cm in height. For the alternative, larger format with up to 4 virtual buttons displayed on each level of the hierarchy, each virtual button measures 5.6 cm in width and 3.1 cm in height. This alternative format was designed to accommodate persons with limited vision or motor control.

The desired content can be presented to the patient in either English or Spanish in the form of text, graphics, or synthesized speech audio output. Text output can be in the form of either a simple list or a checklist that enables the user to maintain procedural orientation by touching the screen to check off each item as it is completed. The rehabilitation practitioner makes the content appropriate to the patient's capabilities by controlling the "depth" of the hierarchy of content, the type and complexity of navigational labels (text or graphics), the content output medium (text, graphics, or spoken audio), and the specific content presented.

Content is not developed directly on the small ISAAC system device. Instead, the rehabilitation practitioner uses the ISAAC authoring system software, which runs on a standard desktop or notebook PC. It can also be used to efficiently update the ISAAC system content whenever changes in the patient's capabilities or situation warrant content change. The authoring system, which appears much like a word processing program, is intuitive and facilitates the entire process of individualized content development and updating. When the content elements have been fully developed, the practitioner simply transfers the content from the PC to the ISAAC system device.

Another important feature provided by the ISAAC system is performance data logging. The performance log provides a snapshot that extends over several days, listing each of the patient's interactions with the system content during that period. In addition to listing patient's actions and the content presented as the result of user initiation, the log also lists the system-initiated content that was presented and the patient's acknowledgments. The log data indicates the sequence, date, and time of each of the patient's actions and the content element presented. Log data is stored in a standard format so that uploaded log files can be imported into most word processing, spreadsheet, and data base programs for viewing, printing and analysis.

Logged data has a variety of uses. It can be used to adjust and refine the patient's individualized content during the initial training period. It can later serve to provide an objective picture of how the system is being used. For example, to identify content areas that are used most, content areas that are not being used at all, and content areas that appear to be used incorrectly. This analysis can help identify when additional task or behavioral training is needed and if content modification is indicated. In addition to helping prevent or minimize problems in community living and employment situations, the logged data can also be used as a tool to monitor and provide documentary proof that prompts (for medications, hydration, meals, vital activities, etc.) were delivered to, and acknowledged by the patient.

It is important to evaluate the appropriateness of the ISAAC system for the patient, prior to investing in the device and training for that patient. As with most rehabilitation tools and interventions, the patient must demonstrate adequate motivation for treatment. Positive premorbid personality characteristics including evidence of accountability and responsibility are advantageous. The family, patient, and clinician must be invested in both the design and implementation of the specific content for the patient. Adequate motor skills to tap a 5.6 cm × 3.1 cm virtual button are necessary. Adequate visual acuity to read 3 cm tall images is also needed. The use of prompts delivered by synthesized

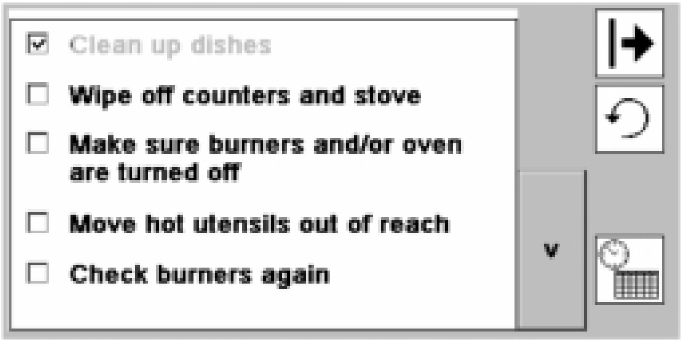

Fig. 3.

speech requires that the patient possess adequate auditory perception. Additionally, the patient needs to be able to follow one-step commands. Finally, the text can only be written in English or Spanish.

Other limitations of the ISAAC system are functions of one of its assets. With mobility, the device sacrifices screen size. The content is insulated from the system user by design to ensure reliability, to prevent corruption of the content, and to increase usability. However, for a small subgroup of higher functioning, computer literate users, access to the content may be beneficial and having to remain dependent on their clinician to update the system may be unnecessarily cumbersome. For these patients, the Essential Steps [2] system may prove beneficial. Secondary to running on a personal computer, this system allows the user access to content and can provide comprehensive support for higher-level skills.

4. The case studies

The current article will discuss two cases that illustrate the effectiveness of the ISAAC system with assisting patients with generalization of rehabilitation to their community living environments. The first case is a patient who suffered an anoxic brain injury secondary to a myocardial infarction. The second case is a patient who suffered a traumatic brain injury. Both patients incurred significant cognitive impairment, from which they were able to successfully compensate with the assistance of their ISAAC systems.

4.1. Case study 1 – A.X.

A.X. is a 31-year-old male who suffered an anoxic brain injury following a myocardial infarction. A.X. evidenced diffuse cognitive impairment with especially remarkable impairment to verbal and visual memory and executive functions. Following discharge from the hospital, A.X. required supervision for safety and was unable to find employment. Consequently, he struggled with poor emotional adjustment, and significant depression. Approximately 18 months post-injury, he entered a multi-disciplinary outpatient rehabilitation program. On admission to the program his level of functioning was assessed using the Functional Independence Measure (FIM®) instrument [12]. He earned a FIM score of 2 (Maximal Assist) for cognitive functions and at a FIM score of 4 (Minimal Assist) for pragmatics. Initiation, memory, compliance with medication management, hygiene, and social isolation were specific problem areas that severely impacted his level of independence. He was easily frustrated when he attempted daily activities, struggled with maintaining social contacts, and was unable to maintain a long-term, premorbid dating relationship.

Premorbidly, A.X lived independently and was successful vocationally in his position as a garden specialist for a home improvement outlet. His previous work history included passenger driver, delivery driver, tractor driver, and pest control worker. He was also a volunteer fire fighter and emergency vehicle driver, and was very active in community organizations.

Following the initial assessment, it was apparent that the level of functional independence A.X. could expect to regain was contingent on his success with compensation strategies. The ISAAC system was considered as an external cognitive device because the patient required procedural guidance for his activities of daily living, as well as cueing to help him initiate activities. Often no one was available at home to cue him, and he stated that he felt defensive when he was constantly being told what to do when someone was at home.

After a brief hands-on assessment using the ISAAC system in a simulated work task, the system was con-

Table 1
Content of A.X.'s checklists

The Morning Routine checklist included:
1. Unplug ISAAC and take with you
2. Make bed
3. Shave
4. Brush teeth and hair using a different brush!!!
5. Get dressed
The Morning Chores checklist included:
1. Feed and water animals
2. Take out trash
3. Check laundry
4. Make any necessary transportation arrangements
5. Return phone calls from yesterday
The Evening Routine checklist included:
1. Check mail
2. Look at tomorrow's schedule
3. Return phone calls
4. Check laundry
5. Check areas to be vacuumed
The Before Bed routine checklist included:
1. Take shower
2. Check pillbox to make sure you took your meds.
3. Take ISAAC to his stand
4. Plug in ISAAC
5. Say Good Night!!!!!
The Saturday Routine checklist included:
1. Make up pill box for next week
2. Make list of refills needed
3. Check and pick up animal food if necessary
4. Call Mom
The Volunteer Fireman Duties checklist included:
1. Get mail from city hall
2. Sort mail
3. Do fire reports if needed
4. Check pagers for replacement if needed
The Before Leaving Home text output included:
1. Get keys, wallet, and pocket knife
2. Get phone and pager
3. Check calendar for daily appointments
The Monday Routine text output included:
1. Call pharmacy to refill prescriptions
2. On fourth of month, make arrangements for Pro-tyne
3. Check post office box for mail.

sidered appropriate for A.X. and likely to provide him practical benefit. He was able to understand the instructions presented by the system during the assessment, demonstrated willingness to use the device and ability to follow the guidance it presented, and was motivated to assist in the identification of problem areas.

Eight routines were identified with which A.X. had difficulty initiating or completing the tasks (see Tables 1a and 1b). Both system-initiated content (computer-initiated synthesized audio prompts) and user-initiated content (detailed procedural instruction presented via the device touch screen) were authored for each routine by his rehabilitation therapists. A labeled virtual button was authored on the device touch screen for each of the eight routines. Checklist format output was then authored for six of the routines (morning routine, morning chores, evening routine, bedtime routine, Saturday routine and volunteer fireman duties). Checklist output includes a checkbox for each item on the procedural list. Text type output was authored for the remaining two routines (Monday routine and his routine before leaving the house).

When a system-initiated spoken verbal prompt from the ISAAC system cued A.X. to perform a routine, he tapped the corresponding virtual button on the device touch screen with his finger to access the related user-initiated content (see Fig. 1). The checklist for that routine was then displayed on the touch screen (see Fig. 2). A.X. performed the first (top) item on the checklist, then touched the check box for that item with his finger. The completed item then disappeared from the touch screen display, so the next item in the sequence appeared at the top of the checklist display (see Fig. 3) . Because the system clearly highlighted the next step the procedural sequence, A.X. did not lose his place in the sequence of procedural items and it was almost impossible for him to miss an item. Text type output consists of a simple list of numbered text items, without check boxes.

Several system-initiated spoken audio prompts were authored to initiate A.X.'s performance of key activities. These included prompts at the appropriate times of day to take his medications, to begin his morning routine, to eat his lunch, to make sure he did eat, to begin his Monday and his evening routines, and to recharge his ISAAC system each night.

The personal and medical information that A.X. commonly needed were also included on his ISAAC system, for easy accessibility when needed. This information included the contact information for key family members he would need to reach in various situations, his medical history, medications used, and doctors' names.

By requiring him to mark each item as soon as he completed it, the checklist eliminated the need for A.X. to remember if each item had been completed. The system-initiated prompts and detailed user-initiated content authored for his ISAAC system reflected his desired basic daily schedule, thus creating effective compensation for his executive and memory dysfunction.

When A.X. initially took his ISAAC system home, he expressed some anxiety about his general ability to use the device correctly, in spite of the training he received in the clinic. In practice, the only significant problem he encountered at home was with locating the recharging connector on the ISAAC system. Reinforcement training by his rehabilitation therapists helped him reliably identify the label on the recharging connector flap, eliminating that problem.

The rehabilitation therapist initially reviewed the data logs weekly. After he had used his ISAAC system for about three weeks, his rehabilitation therapists modified his routines slightly, and another system-initiated spoken audio prompt was added to remind him to check to see if he had taken his medications. This additional prompt proved effective in increasing his compliance with his medication regime. At three weeks, performance data from his ISAAC system indicated that he was successfully performing all routines as designed. Consequently, review of his data logs was reduced to a monthly basis.

At discharge from cognitive therapy, A.X. achieved FIM scores of 6 (modified independence) for attention and memory, a 6 for problem solving, and a 7 (complete independence) for pragmatics. Significant gains were also noted in the patient's self-confidence. As he gained greater independence, he was able to return to his volunteer activities and eventually became employed as a security guard. A.X. used the ISAAC system for approximately 11 months, during which time he progressed to the point where he no longer required the level of support provided by the device. At that point, his established routines were substantially internalized, and he was able to function adequately using a traditional daily planner.

The ISAAC system proved effective in addressing A.X.'s executive and memory deficits, especially initiation, which also led to marked improvement in his emotional and social adjustment, as measured by his self-report. As his confidence in his ability to complete daily routines grew, his interaction in the community increased, and he made great strides in establishing social contacts. Furthermore, the ISAAC system was important in prompting him to take his medication. The wearable design of the ISAAC system made it possible for A.X. to have his ISAAC system and all its features with him and accessible throughout the day. This portability enabled the consistent, reliable, long-term delivery of these supportive prompts that were key to the high degree of functional improvement and independence A.X. was able to attain.

4.2. Case study 2 – B.X.

B.X. is a 31-year-old male who suffered a traumatic brain injury secondary to a motor vehicle accident. B.X. exhibited multi-focal cognitive impairment with marked executive dysfunction. Radiographic studies demonstrated fractures to the roof of his left orbit with an underlying contusion in the left frontal lobe. At eight weeks post-injury, B.X. came to the outpatient rehabilitation program directly from the inpatient rehabilitation unit. On admission to the outpatient program, B.X. presented with a FIM score of 3 (Moderate Assist) in the areas of attention, memory, and problem solving. He evidenced significant executive dysfunction including, impaired self-monitoring, initiation, impulse control, and organization and planning. B.X. demonstrated very poor safety judgment and emotional control. Complex attention, memory, and learning were also significantly impaired. Consequently, B.X. required 24-hour supervision for safety. Removal of this restriction became the initial treatment goal. In order to accomplish that goal, strategies would be necessary to assist initiation and memory of his daily routines and to cue him to monitor safety issues, especially in the kitchen.

Premorbidly, B.X. worked as a supervisor at an industrial company, with duties including supervision of employees, operating machinery, and climbing ladders. He is a high school graduate. B.X. considers himself a handyman and has a workshop in his backyard. The severity of his cognitive impairments precluded his return to work or working in his shop at the time of his admission to the rehabilitation program. His goals included cooking for himself and completing home improvement projects from his workshop. His wife and parents were very supportive and involved with his rehabilitation, improving his prognosis for his regaining a significant degree of independence. His prognosis was also improved by his premorbid characteristics of responsibility and personal accountability. He was, therefore, seen as a strong candidate for the ISAAC system.

After approximately one month of interdisciplinary treatment, B.X.'s occupational therapist, speech therapist, and vocational specialist jointly concluded that the ISAAC system was a viable tool for implementing external memory and initiation strategies to reduce the significant obstacle his cognitive impairment continued to pose to attaining independence at home. Prior to the introduction of the ISAAC system, B.X.'s perceived limited progress toward lifting his safety restriction began to negatively effect his emotional adjustment. Gaining the ability to stay at home unsupervised also took on even increased importance due to the need for his spouse to return to work. Therefore, the ISAAC system was introduced and, with the as-

Table 2
Content of B.X.'s checklists

The Morning Routine checklist included:
1. Shower
2. Get dressed
3. Wake wife
4. Eat breakfast
5. Finish getting ready
6. Put on ISAAC
The Evening Routine checklist included:
1. Fold laundry
2. Check tomorrow's schedule
3. Make sure doors are locked
The Before Cooking checklist included:
1. Gather ingredients
2. Gather utensils needed
3. Set oven to correct temperature if needed
4. Follow recipe
5. Go to "After Cooking" list
The After Cooking checklist included:
1. Clean up dishes
2. Wipe off counters and stove
3. Make sure burners and/or oven are turned off
4. Move hot utensils out of reach
5. Check burner again

sistance of his wife and his speech therapist, authored to provide checklists for B.X.'s morning and evening routines. These routines were developed to mirror his activities prior to injury.

The top level of the ISAAC system user-initiated content display had six virtual buttons: morning routine, evening routine, cooking safety, medical information, personal information, and employment information. Tapping each of these virtual buttons on the device touch screen caused the checklist for the corresponding routine to be displayed (see Table 2). As each item on a checklist was completed, B.X. tapped the check box for that item on the touch screen and it disappeared from view. This feature of the checklist was especially helpful as it eliminated the possibility of repeating a step. It also decreased distraction. To monitor his safety in the kitchen, a "before cooking" and an "after cooking" checklist were designed. The last item on the "before cooking" list was to access and perform the "after cooking" checklist.

The ISAAC system was authored so that 15 minutes after the "after cooking" virtual button was tapped a system-initiated spoken audio prompt reminded him to "make sure the burners are turned off and the hot utensils are in a safe place". Other system-initiated spoken audio prompts were authored to initiate B.X. to take his medication at the appropriate times of day, with follow-up verification prompts 15 minutes after he should have done so. There were also system-initiated audio prompts to remind him daily to take his ISAAC system with him each morning and to recharge it each night. The audio prompts were computer- initiated synthesized speech.

B.X. initially had difficulty finding the system charging connector even though its cover is marked with a yellow lightening bolt to indicate the location. He required assistance from his spouse for several days to learn this recharging procedure. Secondary to B.X.'s difficulty with the recharging process, his ISAAC system content had to be reloaded on the device due to the battery becoming depleted. This reloading was easily accomplished using the ISAAC authoring system and the copy of B.X.'s system content on the rehabilitation facility's computer. Reloading required only a short period of time, and was accomplished while the patient was attending therapy. A family training module was added to the protocol to further assist B.X. in learning to recharge his ISAAC system. In addition, B.X. practiced the recharging process with program staff several times at different intervals to insure proficiency.

B.X. was discharged from outpatient rehabilitation following four months of treatment. At discharge, he met his goal of independence at home and his safety restriction was lifted. His FIM scores had increased to 6 (Modified Independence) using external strategies, including the ISAAC system.

B.X. used the ISAAC system for approximately one year, during which his performance and independence continued to improve. After one year of use, he and his family felt that he had improved to the point that he no longer required the assistance of the ISAAC system. His routines were established and internalized, and his personal safety was no longer an issue.

B.X. likely could have benefited more from his ISAAC system in the early portion of his treatment, if the initial training had been more thorough regarding the recharging process. The system operation procedures that must be mastered by the patient are few, very simple, and largely self-cueing. However, B.X.'s difficulty with the recharging process demonstrates the importance of performance-based training of those procedures. Family members should also be educated in the procedures so that they can provide assistance and reinforcement in the first days following introduction of the system. As demonstrated by this case, the well-designed PC-based ISAAC authoring system used by practitioners makes changing or reloading a patient's ISAAC system content easy and efficient. If the family, patient, or clinician delineate improvements or changes, they are made in the patient's file on the authoring system and then transferred to the patient's

ISAAC device. The ISAAC system is most effective when members of the interdisciplinary treatment team integrate the use of the ISAAC system into their treatment with the patient. B.X used his ISAAC system at home and then brought it with him to therapy sessions, during which modifications could be discussed and any necessary changes could be made immediately.

In summary, at the very least the ISAAC system enabled B.X. to remain at home unsupervised sooner than if he had to rely on written reminders, phone reminders, or "to do" lists alone. Beyond that, it appears likely to have been a significant contributing factor in increasing the degree of functional capacity and independence that he was ultimately able to regain. Additionally, his wife and parents reported significantly improved relationships with B.X. following the implementation of the ISAAC system, secondary to their no longer being placed in the awkward role of supervising his performance of routine tasks.

5. Conclusion

The two cases presented are typical examples of the functional independence that can be achieved through the use of the ISAAC system. They also highlight the importance and potential of cognitive assistive technology generally. As greater numbers of patients survive previously fatal conditions, there are increasing numbers of individuals struggling with severe, long-term cognitive impairment. A number of factors, ranging from severely limited insurance coverage of practitioner and caregiver services to the general lack of adequate transportation make it impractical or even impossible to provide adequate long-term services and supports for these patients through traditional practitioner and facility-based means alone. Therefore, the development and the widest appropriate use of technology-based supports are not only desirable, but also necessary.

As electronics and computer technology have advanced, several attempts have been made to develop or adapt products for use as cognitive prosthetic systems. Most have achieved some success with fairly narrow segments of the cognitively impaired population. Common obstacles to their wider success include difficulty of use, which limits their effectiveness to only the small group of patients with the mildest of impairment. These devices are often difficult and time consuming for practitioners to implement and update. PC-based systems are obviously not portable and, therefore cannot be available to patients in most normal daily living environments for the majority of the day. Many do not include the necessary capabilities to address a sufficient range of most patients' cognitive disabilities, or the manifestations of those disabilities. For example, pager-based systems, which can be effective for cueing, do not provide "on demand" user-initiated access to supports whenever they are needed by the patient. And, alarm sounds alone, which are common with adaptations of PDA's and similar devices, have little significance and provide no detailed assistance to the patient who cannot be sure if a given "beeping" sound signifies "time for lunch" or "time for medication." Most systems cannot be reliable over time because the content is not protected from inadvertent deletion or corruption by the patient. This is especially true of most PC-based systems and scheduling and note taking systems derived from commercial PDA and electronic organizer products. Voice recorders suffer from a combination of almost all these shortcomings.

In contrast, the ISAAC system's design addresses all of the shortcomings discussed above. It was designed specifically as a cognitive prosthetic system and to meet the requirements that entails. When patients are properly selected to use the ISAAC system and sufficient training on the system is provided, it can prove very effectiv at improving patients' functional independence. Proper selection includes attention to premorbid personality factors, such as personal accountability, which improve patients' rehabilitation potential generally.

It is our hope that funding sources will soon recognize the potential power of cognitive prosthetic systems, so that the financial obstacles that currently restrict most patients from obtaining these devices will be removed. A well designed experimental investigation of the ISAAC system with adequate sample size is needed. This research is necessary to demonstrate the viability of cognitive prosthetic systems to the general rehabilitation community, which in turn is necessary to make significant inroads with funding sources.

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