Designing a Cognitive Aid for the Home:
A Case-Study Approach

Jessica Paradise[1], Elizabeth D. Mynatt[1], Cliff Williams[2], John Goldthwaite[3]

[1]College of Computing
GVU Center, Georgia Tech,
Atlanta, GA, 30332-0280
{paradise,mynatt}@
cc.gatech.edu

[2]School of Biomedical
Engineering, Science &
Health Systems
Drexel University
cwilli@drexel.edu

[3]Center for Assistive Technology
and Environmental Access
GVU Center, Georgia Tech,
Atlanta, GA, 30332-0170
john.goldthwaite@arch.gatech.edu

ABSTRACT

Cognitive impairments play a large role in the lives of survivors of mild traumatic brain injuries who are unable to return to their prior level of independence in their homes. Computational support has the potential to enable these individuals to regain control over some aspects of their lives. Our research aims to carefully seek out issues that might be appropriate for computational support and to build enabling technologies that increase individuals' functional independence in the home environment. Using a case-study approach, we explored the needs and informed the design of a pacing aid for an individual with a cognitive impairment whose quality of life was negatively affected by her inability to pace herself during her morning routine.

The contributions of this research include insights we gained with our methodology, two sets of design dimensions: user-centered contraints developed from capabilities and preferences of our users and system-centered capabilities that could be explored in potential designs, a design concept which illustrates the application of these design dimensions into a potential pacing aid, and evaluations of paper prototypes guided by the design dimensions.

Keywords: Cognitive impairment, traumatic brain injury, case study, pacing, home

INTRODUCTION

Every year, millions of traumatic brain injuries (TBI) occur in the United States alone, and researchers make a conservative estimate that around 1.3 million of these injuries are classified as mild. [4] Many people classified in these categories are able to return to their pre-morbid level of independence, but an often-overlooked portion has trouble returning to their prior lifestyle. Cognitive impairments play a large role in their decrease in independence.

Home life for these individuals is often difficult. Some are forced to give up their jobs after their injury, and fight to remain a functional part of their family unit. Family dynamics often change as a result of the injury, where parent-child roles are reversed, or spouses must pick up the slack for their significant other. The individual can easily get frustrated when he sees control over his life slip away. This frustration combined with irritability, one of the common physiological affects of a TBI, causes additional strain on the individual and his family. A seemingly mild injury can have profound effects on individuals' lives.

Often, dysfunctional high-level cognition makes the most routine day-to-day tasks difficult for these individuals. Regaining control over some of these tasks can help the individual feel more in control of his changed life. We see this as an opportunity for computational support. For example, individuals with cognitive impairments can use computers to aid in remembering and planning daily tasks, while data from sensors in the environments can be combined to recognize activities of the individuals. Our research aims to carefully seek out issues that might be appropriate for computational support and to build enabling technologies that increase individuals' functional independence in the home environment.

In this research, we investigated the design of a system that provides support for users to pace themselves while getting ready in the morning. Our design was motivated and informed by an individual, C, who has survived a mild traumatic brain injury. In cooperation with C and her caregivers, we did fieldwork in C's residence to identify problem areas in her day-to-day home life and formed a detailed understanding of her primary issue, getting ready on time in the morning. We then extracted from the field work a set of user-centered and system-centered design dimensions and used these dimensions to inform the design of a prototype. Finally, after showing this prototype to C and her caregivers (the staff at her residence), we did evaluation interviews based on the design dimensions to elicit their reactions to the design.

The methodology that we applied for this case study presents several suggestions for working with people who have cognitive impairments, including the need to pair our subject interviews with cargiver interviews to aid in the interpretation of data. The design dimensions we uncovered during our nine-month case study encapsulate user-centered constraints stemming from the capabilities and preferences of the end users of a cognitive aid in the home, as well as the range of system-centered capabilities that could be explored in potential designs. Additionally, our proposed design concept illustrates the application of these design dimensions into a potential pacing aid. Our evaluation demonstrates the utility of evaluating simple paper prototypes to uncover unanticipated applications of the proposed system, and the use of the design dimensions to guide the evaluation inquiries.

COGNITIVE IMPAIRMENTS IN A HOME ENVIRONMENT

Cognitive impairments and particularly impairments stemming from traumatic brain injuries are inherently multi-faceted resulting in a myriad of interacting symptoms that are manifested as memory impairments, attentional deficits, difficulties in planning and executive control, and anti-social behavior [7]. The combination of these impairments varies per individual with TBI. In this work, we focus on a combination of attention and planning impairments and how they affect a person's ability to pace herself during a common daily task. Although we use a case-study approach and concentrate on designing for a particular individual, we anticipate that lessons from this case-study and design will apply to other individuals who grapple with a similar set of impairments.

In this research, we address the design of a computer-based cognitive aid for a home setting. With exception of telerehabilitation [2], the use of computational technology to address the needs of people with cognitive impairments has focused primarily on work and educational environments [3]. However there has been substantial work by rehabilitation therapists in creating paper-based aids to support daily home activities [7]. Our aim with this research is to merge these disparate efforts. Of particular interest is how the additional constraints of designing for the home, such as minimizing technical complexity, designing visual and physical forms that are aesthetically pleasing in the home, and minimizing the burden on the caregiver, shape the use of computational systems.

METHODS

Coming from a human-computer interaction perspective, we first set out to understand the problem domain by conducting a literature review, talking to domain experts, and visiting rehabilitation hospitals. By adopting a case study approach, we did field work to identify problem areas in the user's day-to-day home life and formed a detailed understanding of one of these issues. After building paper prototypes of the system, we conducted evaluation interviews based on two sets of design dimensions that evolved from our fieldwork.

Selection Criteria

Adult survivors of mild to moderate traumatic brain injuries were considered for participation in this research. The survivors must have cognitive impairments due to the injury and a desire to participate in this research. Additionally, we look for survivors with a strong desire for independence who are relatively independent.

The participants were recruited through a residential program for survivors of a traumatic brain injury. On entry to this program, residents are subjectively evaluated for their level of independence by staff. The staff identified specific residents who meet our selection criteria. We approached two residents about the research, and for logistical reasons only C was a good match. C and her legal guardian gave informed consent to participate in this research.

The secondary participants in this research are the staff members of the residential program where C lives. They are both her caregivers and experts in the area of TBI. Three out of the six residential staff members participated in the research. Each staff member we interviewed gave us informed consent.

A Case Study

We took a case-study approach because of past success with case studies seen in Cole's work developing cognitive prosthetics for clients with mild traumatic brain injury. [1] We conducted a series of ethnographic-style observations and interviews at the primary participant's residence over a nine-month period. Each interview with C was paired with an interview with a staff member. We did three general observations to become acquainted with staff and the residents. We paired our six interviews with C with staff interviews. Many informal staff interviews took place over the course of the research in addition to the six formal interviews. We also spent one morning observing C and the staff during their morning preparations. We evaluated a paper prototype of our design concept with two staff interviews and one interview with C.

C AND HER HOME ENVIRONMENT

C is a woman in her mid-forties who sustained a mild closed head injury in a car accident seven years ago, which left her with cognitive and physical deficits. She has executive dysfunction primarily in her judgment ability and ability to see the long-term ramifications of her actions. She battles with anxiety and depression, and has vestibule problems that make her dizzy and have trouble balancing. The vestibule and cognitive deficits decrease the speed of her physical activities and her speech. Any vision difficulties she experienced are mostly corrected through surgery. Staff also reported that she has difficulty multitasking and with staying on task.

C lives with five other individuals in a residential program primarily for survivors of brain injuries. One or two staff members are always present to assist residents with medication, cooking and transportation to their activities. C has her own bedroom and bathroom off her room that she

shares with the staff. She enjoys volunteering at local churches several times a week, and goes on group outings to feed the homeless.

C is the mother of three adult daughters, the oldest of whom is her legal guardian. This role reversal is a cause of stress in her life, and is one of many reasons that she feels lack of control over her life. She is frustrated with her living situation, and her doctors tell her that she will never live on her own again. Currently, the staff also feels that C does not completely understand her own limitations.

C'S TARDINESS

Method

At this stage of the research, we conducted a series of interviews with C and the staff to uncover and understand problem areas in C's day-to-day home life. When we initially paired C's interviews with staff interviews, we assumed that C and the staff would have slightly different perspectives on C's problem areas.

As it turned out, in addition to adding another perspective, the staff were invaluable in providing a framework for us to understand C's interviews at these beginning stages. C passionately discussed many different issues and frustrations with her life and illustrated these issues and frustrations with specific events. The manner in which she discussed these events made it seem that they happened sometime in the distant past, and details were sometimes jumbled and sparse. When we asked the staff to describe C's problem areas, without our prompting they illustrated their points with the same events that C discussed many of which turned out to be current. They provided the additional context needed to understand the situations.

Results

C and the staff highlighted her finances and her tardiness as the critical areas where C needs help. The finance issue is too personal for the staff to intervene, so we chose to look into the tardiness issue. This is an important issue for her because it has caused her problems in the past. She continually makes other residents late and has temporarily lost public transit privileges in the past. Her tardiness is a source of tension between C and the staff.

Currently, C uses cues to help pace herself in the morning, though the cues are not always timely or accurate. She described relying on a fellow resident who uses a wheelchair as a guideline on whether she is tardy. In one incident when she was left behind at the house due to lateness, she noticed that the footrests from the wheelchair were still on the back porch. She assumed that since the footrests were still there that the fellow resident was not yet loaded into the van, which in her mind, meant that she was not running late and did not need to rush getting dressed. As it turned out, the staff was leaving the footrests behind that day, and the resident was already loaded into the van. Many other times, C did not realize that she was running late until the bus pulled up to the house. In both of these episodes, C uses external cues to aid in determining if she was tardy,

though the cues were too late to help her pacing, and were not always accurate.

Tardiness was a problem for her pre-injury as well according to second-hand reports by past co-workers reported by staff members. The tardiness problem is now exascerbated by her injury. Another confound is that she does not like to be early and have to wait for other people. On the other hand, her past use of external cues makes us hopeful that if she were provided with consistent and accurate pacing aids that she could be timelier.

C'S MORNING ROUTINE

Method

We took several approaches to uncover specifics about C's morning routine. We first attempted to have C do a "grand tour" of her morning routine, walking through the actions and describing them to us. [6] Despite our attempts to keep her on topic, C became sidetracked during most steps in the process.

To make the "grand tour" interview technique more concrete for C, we developed an exercise to work through the morning routine on paper. We included a few centering questions to focus on that morning such as: "What time did you get up this morning?", then had her check off activities that she did that morning from a list that we developed based on past interviews. Together with C, we transferred each activity to separate forms that we developed and answered questions on the forms about the activites like: "What do you need to do for this activity?" and "About how long does it take?" We then had C order these forms chronologically and encouraged her to verbalize her routine as she ordered the forms.

Due to the length of these exercises, we spent two sessions working with C to get a relatively complete picture of the morning from her perspective. In the end, these forms were invaluable to aid C in recovering specific details about the morning.

Additionally, we spent a morning in the room adjacent to C's bedroom and the kitchen as C was getting ready to go to a scheduled event. This vantage point gave us an impression of the level of staff intervention and the gross timing of activities without invading C's privacy or getting in the way of staff. This method did not allow us to acquire specific details of activities, since we were not actually in the room with C. Currently, one morning is sufficient for our purposes. If we decide in the future that more detailed data is critical, more observations will be necessary to improve the reliability of the observations.

Results

C appears to have a consistent base routine that she follows each morning. She is able to tell us the list of activities and rough estimates of the time they take. It is unclear at this point how accurate these times are, and a morning staff member felt that they are low estimates. The routine is clustered by location as you can see in Table 1.

Activity	Location	Reported Time Spent that Day
Hit snooze alarm/get up	Bedroom	An hour and 15 minutes
Put on robe	Bedroom	A few minutes
Go to the bathroom	Bedroom	Less then 5 minutes
Brush teeth	Bathroom	4 minutes (on a timer)
Brush hair	Bathroom	Less than 5 minutes
Get breakfast ready	Kitchen	Around 5 minutes
Eat breakfast	Kitchen	At most 30 minutes
Take medicine	Kitchen	Depends on staff
Clean up dishes	Kitchen	At least 15 minutes
Get dressed	Bedroom/ Bathroom	At least 30 minutes
Brush teeth	Bathroom	4 minutes (on a timer)
Put on makeup	Bathroom	About 15-20 minutes
Do hair	Bathroom	Not reported
Go to the bathroom	Bathroom	Less than 5 minutes

Table 1. Chronology of C's morning routine and location of activities

According to staff, there are several trouble areas in her routine. The biggest problem is that she oversleeps. She and staff reported that C will either hit the snooze alarm or sleep through the alarm for at least 45 minutes. One of the reasons she oversleeps is because she stays up too late the night before. Staff also told us that often times five to ten minutes before she is supposed to leave, she is not dressed.

The transition from the kitchen back to the bedroom appears to be difficult for C to get through. She becomes distracted by phone calls around this time, and often wanders back to the kitchen thinking that she has forgotten something. Each trip to the kitchen adds considerable time to getting ready primarily because she gets distracted and side-tracked once there.

INTERPRETATION: DESIGN DIMENSIONS

The culmination of interviews, observations, and paper-based activities led us to explore designing a pacing interface that would aid C in successfully completing her morning routine in time to meet the scheduled transportation services. Our field work did much more than inspire the need for this tool, it also served to illuminate a number of key design dimensions that we needed to address. These dimensions fall into two categories, and a summary of the dimensions is found in Tables 2 and 3.

The user-centered design dimensions represent the capabilities and preferences of our user group, namely C and the staff. These dimensions likely also apply when designing other cognitive aids for a home environment. In the following section, we discuss how to interpret and prioritize these dimensions for C and the staff.

The system-centered dimensions represent a spectrum of technological capabilities, from the overall intelligence (or "smartness") of the system to its form factor. These dimensions should apply in the design of many information appliances that reflect and support the completion of a sequential task. For our design, we needed to balance the technology and interface possibilities with the design constraints stemming from the user-centered design dimensions.

Dimension	Description
Perception of control	Degree to which C feels in control of the interaction
Appearance	Pleasing decor for a home environment
Burden on user	Routine effort required by the user
Non-distracting	Degree to which C is not negatively distracted from her morning routine
Ease of use	Overall usability
Design simplicity	Simple design, not intimidating or overwhelming
Burden on staff	Routine effort required by the staff

Table 2. User-Centered Design Dimensions

Dimension	Description
Interaction: User Prompting	Degree of proactiveness in alerting the user and the method of alerts
System Input	Method of input into the system through different modalities such as touch or voice

Table 3. System-Centered Design Dimensions

Dimension	Description
System Intelligence	Degree of awareness and knowledge of C's current actions
Display of History	Degree to which the interface includes information about previous days
System Mobility	Mounting the display at a known location(s) or providing a mobile device
External Cues	Incorporates information about external events as pacing cues

Table 3. System-Centered Design Dimensions

User-Centered Design Dimensions

Perception of control is the most important of these dimensions. Lack of control over her life is a major issue to C, so the system must be designed in a way that both makes C feel in control of the system and enables C to regain control over her morning routine.

Appearance of the system is also an important design consideration. C is greatly concerned about the appearance of her personal space in her home environment, so this system must be aesthetically pleasing to her and blend into her decor.

A distracting system would make C even more tardy, so we must take care to minimize distractions in a system for her. Similarly, a difficult to use system with high demands on C will likely overwhelm her, and cause her to abandon its use. In general, when designing aids for users with cognitive impairments where the focus of the user's attention is not on the aid, but on an external task, the design cannot be complex otherwise it does not effectively support the task at hand.

In addition, the system cannot place too much burden on the staff because they are already busy in the morning helping other residents get ready.

System-Centered Design Dimensions and Interrelationships

As mentioned above, the system-centered design dimensions represent different levels of technological capabilities that must be balanced with the user-centered design dimensions. The following is a discussion of some of these tradeoffs.

System prompts can become distracting and annoying for any user, much less someone with a known cognitive impairment. The system must achieve a careful balance between giving the user useful and timely prompts and nagging or being overwhelming. The user's perception of control and the general social acceptability of this system could dramatically change through different implementations of this dimension.

Input to the system could be done through different modalities. We hypothesize that some modalities will aid in pacing more than others. For example, perhaps using a touch screen interface will help C to regain her focus on activities better then using a voice interface because a voice interface may easily distract her given C's social nature. In addition, the modes of input may affect C's perception of control over the system.

Intelligence of the system ("smartness") refers to the degree to which the system is able to recognize activities. For example, the system could recognize that C has brushed her teeth and automatically "check" that activity off. However, to preserve C's control over the system and to follow the lead of cognitive rehabiliation strategies, the system should have C enter or confirm the steps as illustrated in the design below.

Presenting history information to C might be beneficial to aid her in pacing. A visualization of the pace of past days and the result of that pace could help her to monitor and judge her progress that morning.

A mobile device has the advantage of portability so C would be able to use it to aid her in the kitchen as well, but it will likely distract C due to its gadget or toylike affordance. In addition, a mobile device has the potential to be misplaced.

Although her strategy is mostly faulty, C uses external cues, such as the actions of other house residents, to inform her pacing. A computational system could incorporate more reliable cues, such as the location of the transportation van as it makes its way to the house. At this point in our designs, we have not attempted to include such external cues given the additional technical complexity of such a system. This area is, however, of great interest in our future efforts.

PROTOTYPE: A PACING AID

Based on the aforementioned design dimensions, we came up with a base design concept with two alternative displays, one being time-based and the other location-based. The dimensions guided us in prioritizing issues of usability and user acceptance while considering the range of technological capabilities and interaction techniques.

The goal of the system is to enable the user to pace herself in the morning so that she is not late getting ready. Its secondary purpose is to help her stay on task, which consequentially may be the key to preventing her lateness.

In general, this system is a collection of touch panels where activities are recorded (or "checked off") when C touches the screen. The display on these panels have several components as shown in Figures 1 and 2. The name of the activity that she is getting ready for is shown with the time she needs to leave the house. The buttons in the display correspond to either a single activity or a group of activities and are the mechanism for confirming completed activities. The final component of the display is the background color which is the method of alerting the user.

The action of touching the activities as C enacts her morning routine is important for several reasons. Cognitive rehabilitation techniques use physical actions such as using a checklist to keep people on track, and to give them
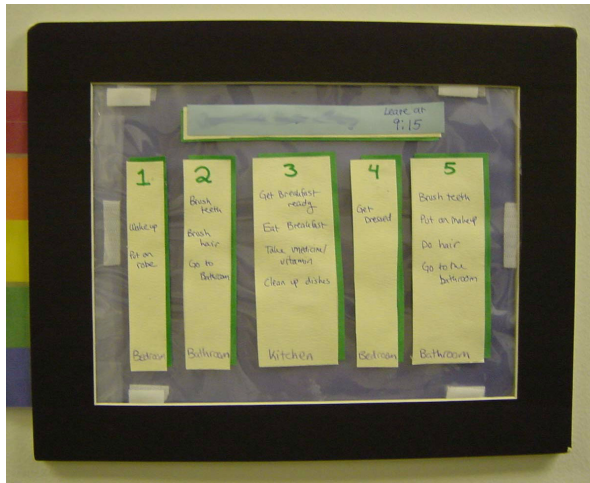
Figure 1: The Time-Based Display

something visual that shows that they are making progress. Additionally, this method reduces the system requirements for complex activity recognition.

If C becomes increasingly late in completing an activity, the background color will start changing similar to the color-scheme prototype of the pacing aid TimeAura [5]. The background will generally stay blue, and if C gets off schedule, it will gradually shade to red depending on how far off schedule she becomes.

One panel will be mounted next to the bathroom mirror, which is where the majority of C's time is spent in the morning. The other panel will be placed in the bedroom near her bureau. Conveniently, there is already a calendar next to the bureau.

When the system is not in use, a picture of C's choosing will be displayed giving the system an appearance of a digital picture frame.

We developed two paper prototypes that compared the spatial organization of the activities (shown in Figures 1 and 2).

- **Alternative 1: Time-Based Display**
  The time-based display (Figure 1) shows the activities in buttons that are shown chronologically from left to right. Each button is a cluster of activities that occur in the same room. As C completes one of these clusters of activity, she touches the corresponding block.

- **Alternative 2: Location-Based Display**
  Physical location is an alternative way to display the activities. The location-based display (Figure 2) attempts to get away from a strict time-linear display to allow for variations in the order of activities. Each activity has a corresponding button that is located inside boxes that represent rooms. The buttons are placed in the room boxes in roughly the location that C does the activity.
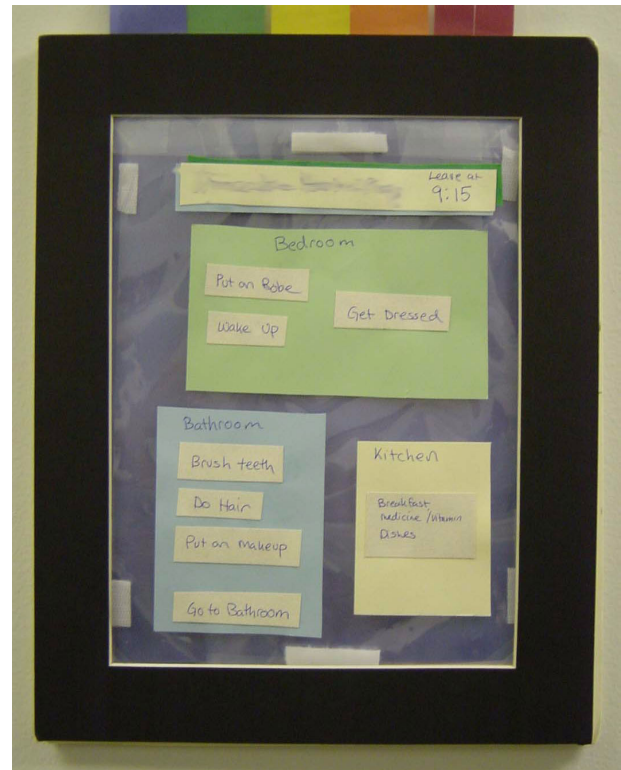

Figure 2: The Location-Based Display

PROTOTYPE EVALUATION

Method

As the beginning of iterative design, we showed the paper prototypes discussed above to the user and two staff members to elicit their reactions to the design. In general, we sought to evaluate the potential of the system to aid C in getting ready in time.

Many of the user-centered design dimensions became evaluation heuristics. We created a brief questionnaire consisting of a series of statements regarding the heuristics such as "C will feel in control of this system." The staff rated the degree to which the design achieved these evaluation heuristics, and we interviewed them to elaborate on these ratings.

Results

Overall, C and the staff reacted positively to the system concept. Everyone felt that the time-based display has strong potential to help and were less positive about the location-based display. The staff expressed desire to build the system and have C try it.

The additional use of the system as a decision aid arose a couple of times in the interviews. One of the staff members also saw the system as a tool to aid C in realizing that she is running too late. The staff member felt that C could then make the decision herself that she cannot make it to her scheduled event. C also felt that this system could aid her in

making decisions about what she has time to do in the morning.

The staff thought we were on the right track in general with the design dimensions. The staff felt that the system will be easy for C to use and that it will not add extra burden to the staff. The staff were divided in their reactions to whether C would feel in control of the system. One staff member was fairly certain that C would feel in control, while the other was more skeptical. This staff member explained that right now C feels like she does not have control in most aspects of her life. She was concerned that in actual use C would feel that this system is taking control of her life. The staff members were unsure whether the system would distract C, but leaned toward it not being distracting. They felt we will have to wait and see.

A summary of the design decisions regarding the design dimensions and the user and staff reactions to these aspects of the designs are found in Tables 4 and 5.

Dimension	Design	Evaluation
Perception of control	User confirms activites rather then automatic recognition and entry of activities	Divided response, staff unsure, C thinks she would feel in control
Appearance	Picture during off-hours	No direct response
Burden on user	Minimal interaction required, alerting is passive	C and staff thought system does not over-burden
Burden on staff	Staff collaboration in initial configuration	Highly positive, staff felt system would not add burden on them
Non-distracting	No verbal prompts, minimilistic and easy to use interface	Staff unsure, further testing needed
Ease of use	Minimal actions required of the user	Staff and C felt it's very easy to use
Design simplicity	Minimalistic approach to features	No direct response

Table 4. User-Centered Design Dimensions — Design Decisions and Evaluation

One major feature that the staff felt was missing was the ability to modify C's target time. They explained that last minute minor changes in the schedule happen often, and the system needs to have the flexibility to work with these changes.

Dimension	Design	Evaluation
Interaction: User Prompting	Passive prompting through changing background color	Enthusiastic response from staff, concern of anxiety from C
System Intelligence	Learns through C's direct input	No direct response
System Input	Touch screen input	Staff agreed on choice of input
Display of History	Indirect through the changing background color	No direct response
System Mobility	Display mounted on wall	No direct response

Table 5. System-Centered Design Dimensions — Design Decisions and Evaluation

CONCLUDING THOUGHTS

In this paper, we presented the methodology and results of a case study about a woman with mild traumatic brain injury that led to the design of a pacing aid. Lessons learned from the methodology, a set of user-centered and system-centered design dimensions, an initial design concept, and results from the evaluation of the design concept are among the contributions discussed.

REFERENCES

1. Cole, E., Dehdashti, P. (1998) Computer-based cognitive prosthetics: Assistive technology for the treatment of cognitive disabilities (in) *Proceedings for the Third International ACM Conference on Assistive Technologies ASSETS'98*, April 15-17, 1998, Marina del Rey, CA.

2. Cole, E., Matthews Jr., M. K. (1999) Cognitive prosthetics and telerehabilitation: Approaches for the rehabilitation of mild brain injuries. In Murner, J. and Ettlin, T. M. (Eds.), HSW-Distorsion & Leichte Traumatische Hirnverletzung Behandlungskonzepte (in English pp 111-120). Basel, Switzerland.

3. Cress, C. J. and Goltz, C. C. (1989). Cognitive factors affecting accessibility of computers and electronic devices. (in) *Proceedings of Resna 12th Annual Conference*, New Orleans.

4. Malec, J. F. (1999) Mild traumatic brain injury: Scope of the problem. In Varney, N. R., and Roberts, R. J. (Eds.), *Evaluation and treatment of mild traumatic brain injury* (pp 15-37). New Jersey: Lawrence Erlbaum Associates, Publishers.

5. Maymakina, L., Mynatt, E., and Terry, M. A. (in) Proceedings for ACM SIGCHI'01 Conference, March 31-April 4, 2001, Seattle, WA.

6. Spradley, J. P. (1979) *The ethnographic interview*. New York: Holt, Rinehart and Winston.

7. Ylvisaker, M. and Feeney, T. J. (1998) *Collaborative brain injury intervention: Positive everyday routines*. San Diego, CA: Singular Publishing Group, Inc.