Increasing Workplace Independence for People with Cognitive Disabilities by Leveraging Distributed Cognition among Caregivers and Clients

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ABSTRACT

In this paper we describe a current group configuration that is used to support people with cognitive disabilities (hereinafter referred to as "clients") in the workplace. A client receiving face-to-face, often one-to-one assistance from a dedicated human job coach is characteristic of this "traditional" model. We compare this traditional model with other group configurations that are used in cooperative and distributed work practices. In so doing, we highlight requirements that are unique to task support for people with cognitive disabilities. A survey of technologies that have been developed to provide clients with greater levels of independence is then presented. These endeavors often attempt to replace human job coaches with computational cognitive aids. We discuss some limitations of such approaches and then present a model and prototype that extends the computational job coach by incorporating human caregivers in a distributed one-to-many support system.

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Design, Reliability, Human Factors

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New social behaviors, Social aspects, Communities

1. INTRODUCTION
Approximately 20 million persons, or 7%, of the general population in the United States alone are afflicted with cognitive disabilities. Based on 1997 estimates the yearly cost in terms of support, long-term care, and lost productivity is more than $100 billion per year [2]. In 2001, the estimate had risen to over $140 billion [18]. A handicap is a limitation on "the fulfillment of a role that is normal for the individual" (e.g., shopping, working, and socializing) [19]. However, a disability does not necessarily result in a handicap or limit participation in society [14]. Fortunately a handicap condition may be overcome by using external tools, such as assistive technologies.

The social environments in which people with cognitive disabilities live and work are unique from the perspective of cooperative work practices and distributive cognition. The knowledge of how to perform a task is shared by people and artifacts. For example, in the case of packing boxes, a person can learn the required steps. A human job coach can then evaluate task execution and can intervene if something goes wrong. Having a human caregiver constantly at hand has a high cost, both financially and in terms of the client's diminished independence and self-esteem. These barriers can be surmounted by the use of appropriately designed and configured sociotechnical systems.

This paper describes the design rationale and implementation of such a system, the MAPS-LifeLine system. MAPS-LifeLine provides a research platform to study the requirements and use of a mobile, wireless, prompting system based on multimedia hand-held devices for persons

with cognitive disabilities and a web-based monitoring and intervention system for their caregivers. Before any design work could be accomplished, we needed to become conversant in the world of assistive technology, especially technology for people with *cognitive* disabilities, as well as the social ecology of caregivers and assistive technology experts. The design of this prototype was informed by a series of site visits and collaborations with subject-matter experts. We also surveyed existing social and technical approaches and studies. This information was examined from a distributed cognition viewpoint, which highlighted the virtues of human support structures and exposed the shortcomings of existing technological approaches. Conversely, we identified limitations of human support and began to explore ways to mitigate these limitations through the design of a sociotechnical solution. As a result, this work informs the design of a usable and useful group system to assist a unique form of social and work support, entitled *distributed support system*.

This paper starts by briefly describing three major contemporary group configurations often employed in cooperative and distributed work practices. These work models are compared with the *distributed support system model*. In so doing, we highlight the unique aspects of the latter, in particular the distributed and coordinated nature of the activities, and the fact that its primary goal focuses on supporting certain individual activities as opposed to the traditional group endeavors in which the primary goal is to create a final *common* tangible object or outcome. This will set the stage for the remaining discussions in the paper, where we will highlight the need for a conceptual underpinning that captures this complex human activity. The concept of *distributed support systems* is then further presented as an important framework for studying as well as guiding the design and development in this domain of computing applications. This is followed by a detailed description of a prototype whose design was based on a series of site observations and the distributed support framework. A unique application of distributed mobile computing to support the increased independence of people with cognitive disabilities and their caregivers is then presented. A final discussion of future work is presented.

2. WORK CONFIGURATION MODELS: DIFFERENT WAYS TO GET THE WORK DONE

Working on complex problems usually requires the collaboration and coordination of experts from various domains. Depending on the problem domain as well as organizational culture, different work configurations are employed to facilitate the interaction, cooperation, and collaboration among these experts and thereby allow the work to be accomplished. These work configurations represent different forms of sociotechnical structures in the workplaces that coordinate distributed efforts and facilitate the accomplishment of the work goals. Many approaches can be taken to analyze the different characteristics of these work configurations. We are particularly interested in aspects that pertain to relations among elements that participate in the activities, be they people or "intelligent" computational agents. In this respect, we are interested in the structures of social relations that characterize these different

configurations, and in practice, determine the forms of interactions and work processes that are supported as well as the kinds of technologies that better meet specific needs.

Table 1 (below) contrasts the particular configuration of distributed support with three major work configurations available in current organizations and work settings. Distributed support is the object of our research and is described in more detail next in this paper. This comparison focuses on the functional and interactional aspects of these configurations that create enabling conditions for the work to get done effectively and efficiently. An important aspect is the way these configurations are brought and held together, as they convey the main motivation for their existence. The roles played by people in these configurations, and how they are defined, assigned, and learned, determine the ways people interact among each other throughout work activities. Finally, the major challenges and opportunities for technological support are contrasted to inform the design of potential technologies to enhance the group activities in these configurations.

The development of work practices facilitates the interaction among stakeholders in significant respects. For instance, well-defined practices allow clear intersubjectivity (i.e., effective and efficient communication and coordination among practitioners), through the development of shared tacit knowledge that is usually discussed as personal, non-articulated, experience-based, and skill-type knowledge. A great deal of current research involves these well-established work practices that do not take place in teams that carry specific work activities. Engeström et al. [8] have developed the concept of "Knotworking" to represent situation-driven work practices that, despite the unique and short-lived combination of people, tasks, and tools, enable very specialized and often complex work accomplishments. Examples of this type of work configuration are airline crews, courts of law, and surgical teams. In these work configurations, there is often no long-term personal relationship among those involved, although there is a great deal of predictability and orchestration in their interaction due to their well-defined practices and individual roles that allow complex work activities to be accomplished.

The most traditional form of work configuration is a project team. In project teams, members (often employees) are brought together by a formal contract, such as a business project or work assignment that holds them together until the conclusion of the project. A project team's main motivation is to accomplish a specific task regardless of its intrinsic complexity, for example, to design and develop a software application. The effectiveness and efficiency of a team stem from its members' shared social practices, which involves long-term relationships, clearly defined social norms, and shared background and knowledge. To achieve this goal, workers are often co-located, which allows such shared practices. Paradoxically, these facts are also the main challenges in creating and maintaining an effective and efficient project team, particularly given the fast pace of social and technological changes of current society that make it difficult to establish such stable social organizations.

In the recent network society [5], new forms of social structures are emerging in work environments to attend to the demand for more flexible, dynamic, and distributed nature of work practices as well as the complexity of the

	Distributed-Support	Project Teams	NetWORK	Knotworking
How do they come into existence?	The need or requirement for external support due to the complexity of the task ay hand (e.g., landing an airplane)	Organizational planning and structuring – work requirements and assignments	Active nurturing and maintenance of one's personal social network to fulfill future needs for support	Sociohistorical development of social practices – long-term development, appropriation, and acculturation of work activities
Working Conditions	Well-defined and bound tasks – different goals among those involved	Problem-oriented situations focus on solving problem/task – revolves around work assignments	Dynamic, transient, itinerant, and often informal – usually involves highly specialized skills for specific work in high-tech companies	Highly distributed, mobile, and well-defined work practice among all involved; does not require much communication due to highly shared background and knowledge
Established Roles	Unidirectional relation between those who support a task and those who are supported in order to accomplish the task	Work assignments – Teams often follow the traditional organizational chart, and most of the times there is a team leader	No specific role in one's personal social network; the role is assigned according to the task	Well-defined so that application to practice is "plug and play"
Duration	Tasks are often short-lived but interactions are continuous without a necessary endpoint	Determined by the work assignment	Short-term projects, but long-term relationships	Specific activities that are often short-lived but repetitive
What holds it together?	Need for support	Work assignment	Social relationships	Well-defined practices
Major Challenges	Communication, coordination, context awareness, intersubjectivity, temporal and spatial alignment, error detection and correction	Team coordination, communication, and knowledge sharing	Nurture and maintain the social network	To learn how to become an experienced and skilled player, and coordination of activities
Technological Support	PDA prompter, GPS and other sensor technologies	Shared calendars, organizational memories	Communication tools, and organization memories	Shared calendars
Example domains	Air-traffic control, caregivers support for individuals with cognitive disabilities or elderly	Assembly-line work	Knowledge workers	Flight crews and surgical teams

Table 1: Work Configuration Models – Main Characteristics

problems that workers attempt to tackle. Moreover, with the focus on downsizing, automation, and outsourcing, organizations are relying on an increasing number of relationships outside their boundaries. In this scenario, a new form of work organizations is defined by the creation, maintenance, and activation of workers' personal social networks (e.g., NetWORK [16]). These intentional networks exhibit both emerging and historical aspects—they are dynamically activated to help an organization accomplish a particular work task, and they draw on established networks of relationships and shared experiences among individuals. The major challenges of this form of organization stem from the "extra" effort needed to create, maintain, and activate in time the social network necessary to address the task at hand. Currently, workers are increasingly required to spend a deliberate and extensive amount of work time to nurture their personal social networks through constant communications and exchanges with members of their social networks.

The two diagrams in Figure 1 (below) convey the major elements that differentiate the work organizations discussed in this paper: who does the work (people), what the roles are and how they are assigned, and what is the driving force (or goal) of the work activity. The squares are the formal boundaries of an organization, whereas the dashed circles are the boundaries of the systems (e.g., social networks) created to accomplish the work. The thick arrows represent the goals of the work activities, or the direction that drives workers' actions. For instance, in *knotworking*, the establishment of well-defined work practices within the formal organization allows the core activity to be represented as roles that different individuals can play without disrupting the main goal of the work activities. In *NetWORK*, the work is achieved by the emergence of a new organizational boundary outside the formal boundaries of the organizations involved. This new boundary, defined by the activated social network, creates the necessary conditions for the work to be accomplished. In contrast, the formal organization
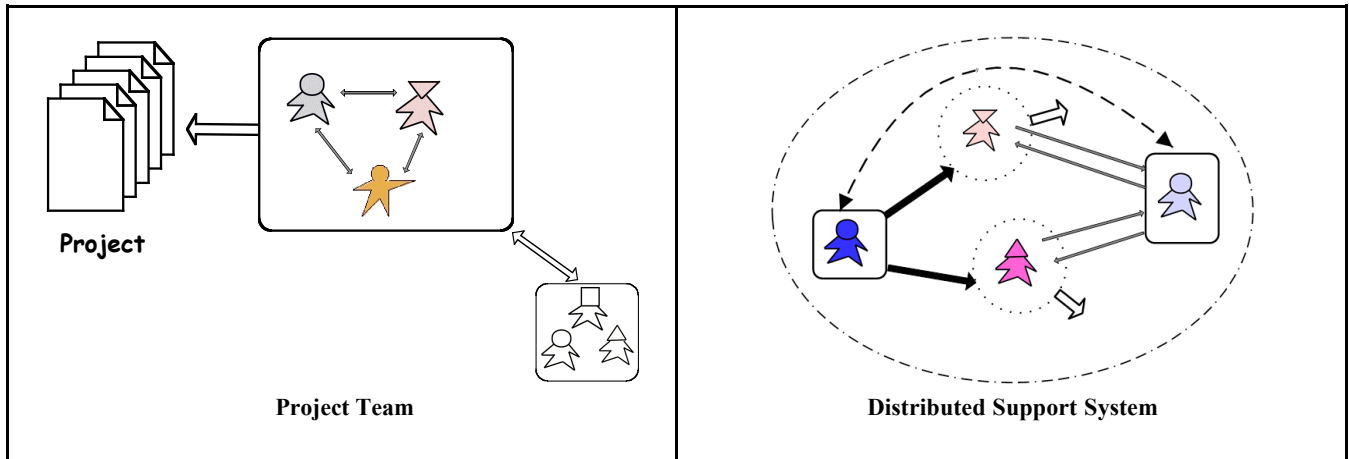
Figure 1: Work organization diagrams—This figure contrasts the traditional team configuration with the distributed support system configuration, highlighting the major difference of that team projects often focus on a common final product or outcome whereas distributed support systems focus on supporting specific individual activities and goals.

boundaries of *project teams* define the roles and people who will work together toward the organizational goals. Finally, in *distributed support systems*, the goals are set to individual activities or people, and their accomplishment is mediated (or supported) by external organizations. The complexity of this approach stems from the necessary interactions between those who support the activities and those who carry out the activities. The rest of this paper further explores the characteristics and challenges of implementing this work organization.

3. DISTRIBUTED SUPPORT SYSTEMS

The major aspect of the previous work configurations that significantly differs from the distributed support model is whether the primary goal of the collective endeavor focuses on producing a final common object or on supporting each other to accomplish particular individual goals. To illustrate this difference, we could contrast a programming team and the air traffic control system that guides our commercial airline carriers. The programming team is focused on producing a "thing"—an application or operating system. All the effort can be measured and any support technology is evaluated against this goal and the selected parameters of the code (i.e., robustness, cost, efficiency, etc.) In contrast, the system of air traffic control, consisting of air traffic controllers, airplane pilots (and navigators), has no "goal"; the measurement it is using is safety and timeliness of the whole system. In this sense, it is the dynamic balancing of the requirements over time that is the "product."

Guided by the distributed cognition framework [20], field-studies, and surveys of existing technologies for increased independence, we have developed two moderately coupled prototypes: the Memory Aiding Prompting System (MAPS), a context-aware prompting system that runs on a hand-held device, and LifeLine, a web-based system that allows caregivers to monitor client activities. The combination of these two systems creates powerful synergies and is hereinafter referred to as MAPS-LifeLine

The model of collaboration that is the basis for our work was built on our analyses of existing *task support systems*. These

systems were developed to facilitate performance of simple tasks by individuals with cognitive disabilities and caregivers. It also differs from the previously presented work configurations in that we are interested in supporting an ecosystem as opposed to traditional work models that support the creation of an artifact by a group or team. Nardi and O'Day define an *information ecology* as "a system of people, practices, values and technologies in a particular local environment" [15]. They describe characteristics of such a system that include *system, diversity*, *co-evolution*, and *locality*. Figure 2 (below) shows that the MAPS and LifeLine applications function together as a *system*. *Diversity* exists as the complementary needs and offerings of the caregiver and client (the person with cognitive disabilities). Two major processes are taking place: (1) the caregiver is designing scripts, which the client uses to complete a task; and (2) the client provides requests (panic and help) and status updates to the caregiver. Through these processes there is a *co-evolution* taking place on multiple levels. First, error trapping and correction allow the script (or plan) to adapt dynamically in real time. Second, usage logs support caregivers in incrementally adapting a script to compensate for inadequate script design or as the client/environment changes over time. One can also see the locality of the MAPS-LifeLine system; the only inputs and outputs not contained within the system boundaries are from the environmental context. This embodies their notion of "a local habitation and a name"—the name identifying what the technology means to those who use it, the habitation referring to the location of the technology within a network of relationships.

To instantiate this information ecology, we need to approach the problem as the creation of a set of systems that support each other, rather than attempting to support the creation of a separate artifact. In order to accomplish this oblique strategy, we use the concept of *symmetry of ignorance* [9]. By symmetry of ignorance, we are describing a design process in which two (or more) subgroups of experts are working together in such a way that one group's expertise provides the complement that compensates for another's ignorance: no one group can complete the task on their own, but together they possess the necessary expertise. A good
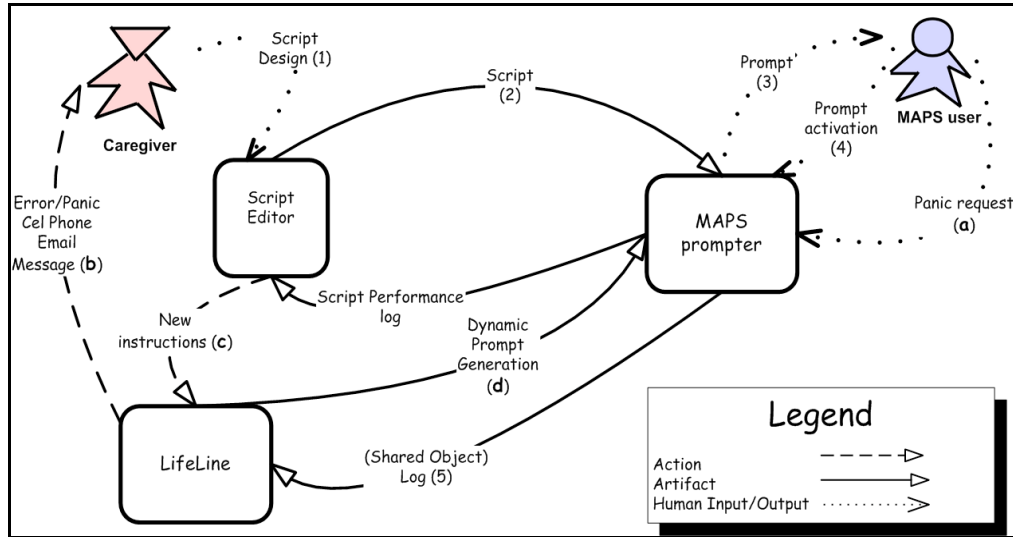
Figure 2: A Conceptual diagram of MAPS-LifeLine

example of the consequences of ignoring the demands of this symmetry is the design of airline reservations systems, as described by Landauer ([13], p. 164–65). The possible number of airline routes and scheduled flights combined with various fare schedules creates a formidable number of items to keep track of, a feat that reservation systems do well; however, the user interface for these systems is so complex that months of experience and training are required to master it. The database and networking of such systems are well done, but the designers were not actually familiar with the day-to-day work practice of reservationists, and therefore the systems are infamous for being difficult to use. In other domains, systems that are designed by domain experts may map well to the tasks at hand, but perform poorly and have many bugs as a result of technical incompetence.

Initial attempts at technical solutions to provide individuals with task supports are promising and provide much of the inspiration for our work. However, they too do not achieve true independence because these technologies have no ability to detect and correct errors. Since not everything can be anticipated at design time, someone must be on hand to help the client manage unexpected contingencies. What are required are portable technologies that provide users with the prompts they need in a manner they can understand and also allow for successful error recovery. However, with technologies that encourage self-determination and independence, there must also be a means for ensuring the security of these individuals as they work and live with less direct supervision.

4. DESIGNING AND DEVELOPING DISTRIBUTED SUPPORT SYSTEMS

4.1 Previous Developments

4.1.1 Living arrangements
Previously, many individuals with moderate to severe cognitive disabilities were cared for in large institutions; however, since the 1970s, most now live in group homes where they receive varying degrees of support [3]. Those who are not in group-homes often live with their families. While

movement into group homes has enabled these individuals to lead more normal lives, it still prevents most from reaching their full potential. Many group home residents are capable of completing numerous day-to-day tasks; however, they require constant reminders of the steps involved, and due to budgetary limitations it becomes easier and often necessary for group home service providers to simply complete the tasks for the individual. For example, it is typically easier for the group home service provider to prepare breakfast for his clients rather than guide each of them through the process. This model limits independence and self-determination while fostering continued dependence on group home service providers. In addition, a client's activity and meal choices are limited by the ratio of clients to service providers. As a result, clients often participate in community activities only as a group. Although being a member of a group can be enjoyable, it limits people from potentially expanding their circle of friends through meeting and interacting with others in the community.

4.1.2 Severe needs—employment
Many individuals with severe disabilities work in supervised employment organizations in which companies send simple tasks to the employment organization for completion. Example tasks may include stuffing envelopes, sorting screws, or folding boxes. These organizations hire several job coaches to assist people in learning the jobs and staying on task. There is a high cost involved in providing the space and personnel to run a supervised employment agency while providing only minimally increased self esteem from having a job as your own. There is little freedom to pursue a job of personal interest and little or no contact with the outside community.

4.1.3 Moderate needs—employment
Those with less severe needs may work in a variety of employment settings in the community completing a range of jobs, such as bagging groceries, janitorial work, or bussing tables. Most begin with a job coach working with them one-on-one, whose support fades as they learn the trade. The job-coach may check in with the employee's supervisor

to make sure things are going well, but the individuals, their co-workers, and supervisors must solve most problems. Other employees may require the job coach's support to mediate problems or remind them of what they need to do as long as they hold the job. Those that require the on-going support of a job coach never experience the feeling of independence. Furthermore, the high cost of ongoing one-on-one job support is prohibitive; thus, those who require it are able to work only very limited hours that job coaches are available. Creating job opportunities can increase the client's self-esteem, but they rarely provide means for them contribute to their own self-sufficiency. Instead, only the most highly functioning individuals can truly be independent at their jobs *and* earn enough money to make real financial contributions to their own self-sufficiency.

4.1.4 Technological attempts to facilitate independence

A PC-based prompting and scheduling tool entitled the VISIONS System [1] uses stationary touch screens distributed throughout the house in an attempt to provide prompts that aid in the performance of simple domestic tasks such as cooking. VISIONS uses a collection of picture cards to assist such away-from-the-system tasks as grocery shopping. Acknowledging the limitations of housebound systems (i.e., support ends when the user leaves the house), AbleLink Technologies developed a line of PDA-based prompting systems that were direct descendants of VISIONS. These include the Pocket Coach and Picture Coach, which provide auditory and visual prompting, respectively [7]. These systems store a sequence of auditory and visual prompts, which the user can step through in a linear fashion by pressing a button as each task step is completed. Even

though Pocket Coach and Picture Coach provided a mobile prompting solution, they had no means to detect errors. For example, this system had no way to detecting whether someone was off task. Also, the device could not help users to recover from errors. For example, there was no way to backtrack if a user signaled the completion of a task step before the step was actually completed (as might happen if the "next" button was accidentally pressed twice in rapid succession).

Often the limitation for people with cognitive disabilities is not an inability to complete a task, per se, but rather an inability to manage the cognitive load of remembering the sequence of steps required to complete a task or how to problem solve when an error occurs. Traditional models require that caregivers monitor individuals with cognitive disabilities as they complete basic tasks, thereby limiting true independence. In addition, activity choices in group homes are made so that the largest number of individuals can participate. This forces all to participate in activities often geared to the individuals with the severest disabilities and allows little time to pursue personal interests. This fosters an atmosphere of dependence, lack of choice, and isolation from the community.

4.2 MAPS-LifeLine Design

In our model of distributed support, a client uses scripts to complete day-to-day tasks that he or she can otherwise not complete without support scripts are created by caregivers by using the MAPS Script Editor (see Figure 3), which helps them to assemble a series of linked pairs of visual and auditory prompts that will aid the client in task completion (e.g., shopping or bus travel). The caregiver is responsible for
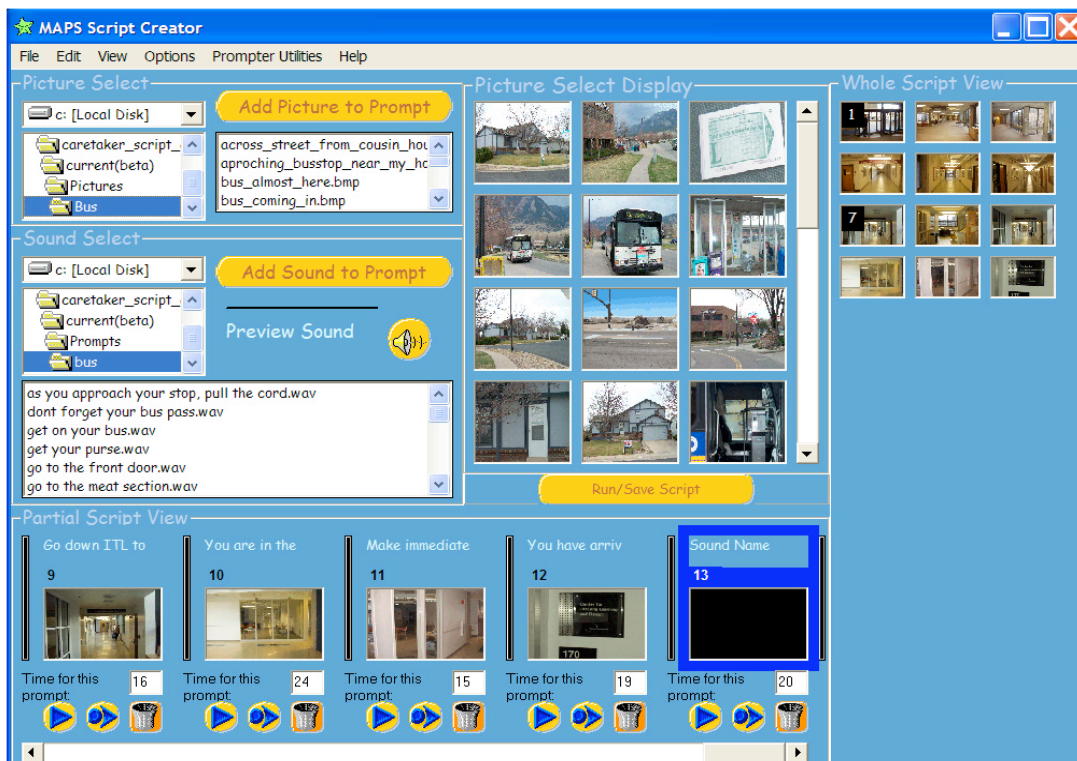

Figure 3: The MAPS script editor

ensuring successful task completion and acts as a sort of air traffic controller to guide the client when necessary. Caregivers create a plan in the form of a script, but acknowledge the possible need to provide guidance or alter the plan in mid-execution. This requires that they not only know the plan that is being executed by the client, but that they also know how the client is performing with respect to that plan and be able to provide the necessary support to minimize deviations from the plan. The LifeLine application, using data provided by the MAPS prompter and external sensors, provides information to the caregiver about the status and immediate needs of the MAPS user. This communication is mediated through a "learn on demand" type message push (e.g., sending a short message system (SMS) message to the caregiver when certain triggers are activated in the LifeLine system).

The MAPS-LifeLine system is primarily a dynamic balancing act and does not terminate in the production of an artifact. It is based upon context and how the relation between the user and the environment reflects the intent of the script or current plan. Therefore, MAPS-LifeLine is as dependent on sensor updates to sets of temporally and spatially posited requirements as it is to user input. The MAPS-LifeLine system then constantly detects and compares sensor information with existing plans, and responds to divergences in the current situation.

4.2.1 Error recovery in a complex world

The use of prompting systems can give clients greater independence; however, with greater independence comes greater exposure to unfamiliar and potentially dangerous situations. Prompting systems that support only simple linear tasks are not equipped to support clients in dynamic settings. The presence of ubiquitous computation allows for the development of more context-aware systems that are better equipped to operate in dynamic settings.

The developers of the Isaac system [12] performed much of the early exploration of personal digital assistants (PDAs) for people with cognitive disabilities. From its earliest stages they acknowledged the need to integrate human agents into the system. By equipping the device with a camera and cell phone to send images to a remote caregiver, error recovery was addressed by integrating a human agent into the system to reassure and assist the client. For example, a client who feels lost can establish voice contact with a caregiver. The caregiver can, in turn, instruct the client to, "Point the camera and show me where you are." After receiving visual and global positioning system (GPS) data about the location of the client, the caregiver might say something such as: "You're in the right place. It looks like they're doing some construction near the bus stop. You should wait on the other side of those orange cones." This type of intervention provides both the knowledge required to solve a problem and the social interaction that is often required to instill trust in the user.

Even though the use of all prompting systems creates some level of distributed cognition, supporting the human-to-human collaboration as Isaac does is a particularly effective approach. It is important not to underestimate the importance of the social interactions provided by this approach; however, in the case of an assisted-living home, the client:caregiver ratio might be in the neighborhood of 8:1. In order to support independent living with scarce human resources, it is desirable to reduce human intervention when circumstances allow.

The MAPS-LifeLine system uses a more dynamic, multi-tiered approach to error detection and intervention. In this approach, the intervention strategy is based on client and error characteristics [4]. In some cases the client will immediately be connected to a caregiver; however, for a higher functioning, more experienced client, the required knowledge *and* social support could be in the form of a computer-generated intervention. In this case the system can provide both knowledge and social support. The higher-functioning client might be given human support only if the computer-generated intervention is inadequate or if the client explicitly requests interaction with the caregiver. (The determination of when the artificial agent should escalate back to a human assistant is a very complex problem that we are currently researching.) This type of dynamic scaffolding creates a more flexible distributed system. Furthermore, it becomes possible to iteratively reduce the attention required by the caregiver. This can happen in two ways. First, the need for caregiver intervention will wane as a client learns a task and becomes more confident. Second, it will be possible to analyze and automate caregiver interventions for common problems. The result is a dynamically balanced system where each stakeholder gets precisely what is needed at the time and in the fashion that is required to extract maximum user benefit

4.2.2 Robustness and fail-safe considerations

During our field study, interviews with caregivers in group-homes, concern for safety, and accountability were among the most common issues that were raised. In considering these issues as well as the analyses of potential situations they might encounter, we identified the following vulnerabilities associated with the physical separateness created by a client's increased mobility.

First, there was a concern with script errors, either due to user actions or changing environmental conditions. MAPS-LifeLine implements error detection by using a combination of internal state monitoring and sensor technologies. While scripts are running, the database that provides visual and verbal prompting does it provide images and verbal prompting or do you mean visual and verbal prompting?] also has metadata about timing and sequence that provides cues that the user is "off track." This is a similar approach to the one described by Christensen et al. [6] that mirrors human activities in computer simulations. Furthermore, MAPS uses GPS and other sensor data (e.g., see MANTIS [11]) to compare reality with expectations. By using these cues to detect an error in context, MAPS and LifeLine system work in concert to provide a tiered, escalating, and user-appropriate set of error correction strategies.

Second, caregivers expressed concern that the wireless connectivity was a weak link in the system. To address this concern, MAPS-LifeLine implements two fail-safe strategies. On the MAPS (hand-held) side it implements redundant wireless connectivity methods: Wi-Fi and wireless PPP dialup. On the LifeLine side, where a stable TCP-IP connection is assumed, it implements polling algorithms. Polling serves two purposes. Associated with each step in a task sequence is a time-to-complete threshold. If this threshold is reached before MAPS signifies the beginning of the next task step, LifeLine will send an SMS message to the

caregiver. This approach permits the trapping of multiple error types, such as: (1) the client has trouble completing a task step, (2) MAPS loses and cannot re-establish a TCP-IP connection, or (3) the hand-held device is physically damaged (e.g., as a result of being dropped) or lost. While these currently implemented strategies provide a functioning safety net, we acknowledge that this is just the beginning

4.2.3 Current prototype implementation

The MAPS prototype is currently deployed on a iPAQ Pocket PC[1] running the WINCE operating system (see figure 4). It is written in embedded Visual Basic (VB) and uses a Sybase Adaptive Server Anywhere database to store and access task scripts that include audio-visual binary data as well as script

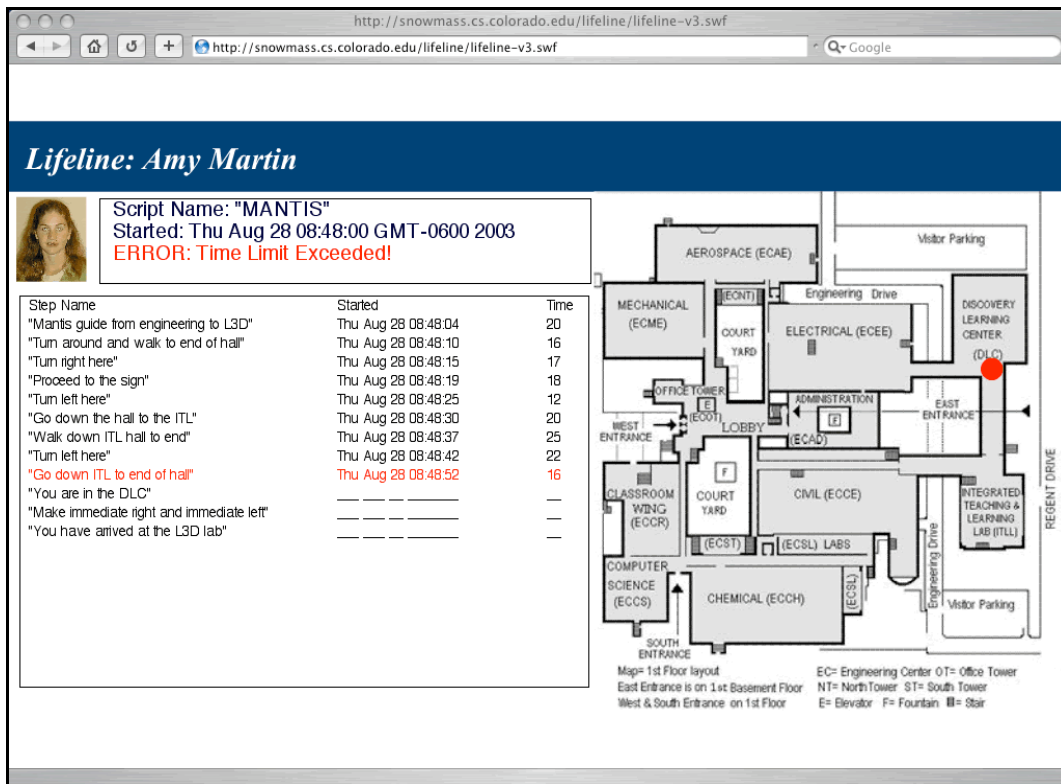**Figure 4: The MAPS PDA prompter**

Figure 5: The LifeLine monitor screen

metadata, such as time thresholds and expected location data.

The LifeLine prototype (see Figure 5) is a web-based application that is written in Flash ActionScript and utilizes the Flash Communication Server, which supports synchronous communication. It consists of two programs: (1) a conduit that runs on the Pocket PC and (2) a caregiver interface that can be run in any web browser. The conduit is responsible for reading a continuously updated log file (generated by MAPS). It then creates and maintains a Remote Shared Object on the Flash Communication Server, which can be read by any web client that is running the caregiver application. The caregiver application displays the client's current status, including current task, step, and location. It also traps for "timeout" errors (described above) and sends

SMS messages via a common gateway interface (CGI) script on an http server.

We have begun studies of the MAPS prompter interface and overall prompting efficacy in the context of a simple glider toy assembly script with students in a local high school. The subjects with cognitive impairments were between 15 and 18 years old, some diagnosed with moderate retardation (DSM-IV classified as 35 - 55 IQ) and several higher functioning individuals (55-80 IQ). The subjects with cognitive impairments were chosen on the basis of working well with verbal instructions and not having significant behavioral issues. The preliminary tests demonstrated that our basic paradigm was applicable to this population. MAPS has additionally done pilot research with typical caregiver populations and the Script Editor interface. After several iterations, our current application reflects the needs and limitations of the target population, in this case moderately

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[1] To test wireless PPP Dialup we used a T-Mobile Pocket PC.

computer literate adult caregivers of cognitively challenged family members.

4.2.4 Illustrative scenario

The prototypes we have implemented demonstrate our approach for distributed support systems. We present here an illustrative scenario that provides a context for the implementation of our system.

Roger and Amy are two adults with developmental disabilities who live at the same group home. Both are eager to have jobs so as to feel more a part of the community, and they like the idea of earning some extra spending money. Unfortunately, previous attempts to work independently have failed due to difficulties staying on task and sometimes getting lost. Amy and Roger have tried working with personal job coaches who closely supervised their work, but this gave them little independence.

Their vocational rehabilitation counselor, Connie, decides to try a computer-based task support system that provides the assistance that Roger and Amy need to do their work, and that has the monitoring capabilities to reassure Connie that they will be safe.

A local technology firm has two job opportunities. One of the jobs requires delivering printer supplies to laboratories as requested; the other involves a daily route of mail delivery and collection. Roger, a relatively high-functioning individual with developmental disabilities, appears to be a good candidate for the mail delivery position, which involves a fair amount of responsibility and problem solving. Amy, who is bit lower functioning, is considered a potential candidate for the printer supply delivery position. There is not as much responsibility associated with this job, and it only requires Amy to follow directions from one location in the building to another. Little decision-making is necessary, but because Amy has a tendency to become lost in large buildings, she will use MAPS-LifeLine to help keep her on track. Connie teams up with the technology firm's supervisor and a job coach to review the required steps for each job and design personalized scripts for Roger and Amy. The MAPS Script Editor provides a wizard that helps them set up default error detection and correction routines for each client. This affects the type of intervention that is provided when certain classes of errors are encountered. For example, for some people, a computer-generated reminder is sufficient, whereas in other cases, a dialogue with a caregiver is necessary to resolve a problem. The job coach and caregiver then assemble the appropriate images and record the prompts for each step in the task script and compile them for Roger and Amy by using the MAPS Script Editor.

After Roger has walked through his job several times and has used the MAPS prompter while being supervised, he is able to begin working independently. Because Roger has relatively strong cognitive skills, the main function of the MAPS-LifeLine Monitoring System will be only to help him when he goes on break, as he often gets distracted and forgets to return. Because of the regularity of his schedule and the building is equipped with a sensor network, it is easy to locate Roger and identify when he needs a reminder. During the second week on the job, Roger remained in the break room for more than 10 minutes after his break was over, so his prompter discreetly reminds him to return to work.

Amy and her team go through similar training and script creation, but because Amy's needs are greater, when she begins her script, the LifeLine monitor is instructed to attend to her tasks on a minute-by-minute basis. Amy's task progress, including her location, can be closely monitored. At first, Connie watched Amy's progress very closely. She saw that Amy was able to complete her tasks with only occasional computer-based intervention (for example, in the beginning Amy made some wrong turns, but with feedback from the sensor network, MAPS was able to immediately detect the error and get her back on track). Reassured by Amy's success, Connie no longer feels the need to continuously monitor Amy's progress; she relies on LifeLine to notify her if a problem arises that the system cannot automatically resolve. On one occasion, Amy got off track and did not respond to the automatic error recovery prompts. When a predetermined time threshold was exceeded, LifeLine sent an SMS message to Connie's cell phone, which informed her of the problem. Connie logged into LifeLine and was able to see the script and the particular step where Amy encountered a problem. She also saw Amy's last known location. In this case, Amy was in the lobby of the building. Connie called Amy on her cell phone and learned that there were vendors in the building and that Amy was browsing the merchandise. Connie was then able to talk to Amy and get her back on task

5. DISCUSSION

In the above scenario MAPS-LifeLine serves as a cognitive aid, supporting diminished executive and memory functions. Some might continue to use it in this way, never learning to work without the aid, while others will learn to perform tasks to the point where the aid is no longer needed. When clients are trained under a traditional model they walk through the task steps with their caregiver. When the caregiver feels the client has learned the task, they covertly observe the client during task performance. After a predetermined number of successful task executions, the client is "certified" and is allowed to perform that task without supervision [10]. MAPS-LifeLine has the potential to significantly accelerate the process. Instead of a process with three discrete phases (i.e., training, covert observation, and unsupervised activity), MAPS-LifeLine blurs the distinction between these phases by allowing support levels to be flexibly fine-tuned. Because of the one-on-one nature of the traditional method, caregivers are limited in the number of clients they can train. MAPS-LifeLine can increase this ratio by allowing caregivers to simultaneously observe multiple clients. Furthermore, observation never actually ceases, although the client may perceive that they are acting without human supervision.

6. FUTURE WORK

Norman [17] points out how people utilize knowledge in the head and knowledge in the world. People with cognitive disabilities have a diminished ability to develop knowledge in the head or interpret knowledge in the world. People without disabilities have shaped the world in which we live. The extent and nature of the knowledge in our world has been designed to serve this majority. Methods are needed for transforming this knowledge into representations that can be easily utilized by people with different needs. A more thorough investigation is needed regarding the way in which clients currently can or cannot perform common tasks with respect to information needs and cognitive demands. It is only through this exploration that we will be able to develop a deeper understanding of how to make this transformation.

We are currently studying various HCI issues involved in script design, such as prompting verbiage and prompting image attribute heuristics in collaboration with other members of the University's Institute for Cognitive Science. Evaluation strategies are being designed for systems whose users cannot effectively communicate their experience with the software and hardware. We are leveraging our work with other group projects that focuses on the accessibility and navigation of public transportation [10].

Most of the features we describe in the illustrative scenario exist in prototype form and are in evaluation; however, a few are part of other research teams and have not yet been incorporated into our prototype. MANTIS is a research project that is developing wireless sensor networks (WSNs) that seamlessly connect into a context-aware smart space [11]. These small computers integrate sensors that track motion, temperature, sound, light/vision, humidity, and a host of other activities. We are currently working with the MANTIS group to embed these sensors into public spaces. We are also working on a specialized MANTI with a compact flash interface that can be attached to the PDA. This specialized device will incorporate GPS so it can determine context information both indoors (via the MANTIS network) and outdoors (via GPS).

7. ACKNOWLEDGMENTS

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