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

Stefan Carmien[‡], Rogério DePaula[‡], Andrew Gorman[‡] and Anja Kintsch[‡§]
{carmien,depaula,agorman,anja.kintsch}@Colorado.edu
Center for LifeLong Learning and Design
[‡]University of Colorado at Boulder
Campus Box 430-UCB
Boulder, Colorado 80309, USA
+1.303.492.1677
[§]Boulder Valley School District

ABSTRACT

This paper describes a group configuration that is currently employed to support the everyday living and working activities of people with cognitive disabilities. A client receiving face-to-face, often one-to-one, assistance from a dedicated human job coach is characteristic of this "traditional" configuration. We compare it with other group configurations that are used in cooperative and distributed work practices and propose an alternative configuration titled *active distributed support system*. In so doing, we highlight requirements that are unique to task support for people with cognitive disabilities. In particular, we assert that the knowledge of how to perform such activities is shared not only among people, but also between people and artifacts. There is a great potential for innovative uses of ubiquitous and mobile technologies to support these activities. A survey of technologies that have been developed to provide these individuals 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 present a model and prototype that extends the computational job coach by incorporating human caregivers in a distributed one-to-many support system.

Keywords
Active distributed support, MAPS, Lifeline, work group organization, disabilities

1. Introduction

Approximately 15 million persons in the United States are affected by cognitive disabilities (Braddock et al., in press). Based on 1997 estimates, the yearly cost in terms of support, long-term care, and lost productivity is more than $100 billion per year (Braddock 2002). Russel and colleagues (1997) define a handicap as a limitation on “the fulfillment of a role that is normal for the individual” (e.g., shopping, working, and socializing). A disability, in contrast, does not necessarily result in a handicap or limit participation in society (LaPlante et al. 1997). Fortunately, a handicap condition may be overcome by using external tools, such as assistive technologies.

The theory of distributed cognition (Fischer 2003; Hollan et al. 2001; Hutchins 1994; Salomon 1993) provides an effective conceptual framework for understanding how groups of people, in conjunction with internal and external tools, can accomplish tasks that are beyond the ability of any single individual. It is a particularly valuable framework for designing and evaluating tools specifically for individuals with cognitive disabilities. In distributed cognition theory, cognition involves mental processes and representations in the mind as well as cognitive artifacts (e.g., written instructions and landmarks) located in the environment. This involves interpreting knowledge in the world and integrating it with knowledge in the head (Norman 1993). Even people without disabilities can have problems interpreting their surroundings; people with cognitive disabilities, however, often have this problem. Our approach is to create socio-technical systems that integrate individuals with cognitive disabilities, human caregivers, and context-aware technologies into an effective information ecology (Nardi and O'Day 1999) for accomplishing complex tasks in dynamic situations (Carmien et al., in press).

The social environments in which individuals with cognitive disabilities (hereinafter referred to as “clients”) live and work are unique from the perspective of cooperative work practices and distributed cognition. The knowledge of how to perform a task is shared by people and artifacts. For example, in the case of packing boxes, a client can learn the required steps from a human job coach, who can then evaluate the execution of the task and intervene as necessary. Having a human caregiver or job coach (in this paper, we use both terms interchangeably) constantly at hand has a high cost, both financially and in terms of the client’s diminished independence and self-esteem. Although this approach has been successful in enabling a number of clients to carry out various types of jobs and achieve higher levels of life satisfaction, it is not scalable and may be limited in the degree to which it can support a wider variety of tasks and cognitive abilities. These barriers can be surmounted by the use of appropriately designed and configured socio-technical systems.

Providing professional and personal support to clients engaged in everyday working and living activities is complex and requires approaches that encompass personalized assistance, coordinated activities, and ongoing assessment and supervision. For such approaches to be effective, they should provide social and technical conditions for clients to perform these activities safely and (to the greatest extent possible) independently. They should also allow caregivers to privately provide clients with effective support. In our research, we investigate a unique configuration of mobile and ubiquitous technologies and practices to help individuals with cognitive disabilities perform these everyday activities (Carmien and Gorman 2003). These activities are characterized by the intimate and constant relationship between the caregiver and the client, in which the major role of socio-technical systems is to facilitate and support both the caregiver in guiding the client and the client in providing feedback about the guidance process, thus guaranteeing the client's success in living more independently.

These factors have guided us to the design rationale and implementation of a socio-technical system called MAPS-Lifeline. MAPS-Lifeline provides a research platform to study the requirements and use of a multimedia prompting system based on mobile, wireless, handheld devices for persons with cognitive disabilities and remote monitoring and intervention systems for their caregivers. Before any design work could be accomplished, however, 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 socio-technical 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 that we call an *active distributed support system.*

This paper starts by briefly describing the traditional job coaching approach to enable clients to carry out certain work tasks independently with varying levels of support and monitoring. This sets the stage for the remaining discussions in the paper, in which we highlight the need for a conceptual underpinning that captures the complex nature of these activities, which are characterized by a distributed, one-to-many support for clients with varying needs and degrees of independence. The concept of an active distributed support system 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. We present a unique application of distributed mobile computing that creates an effective cognitive ecology (Hutchins 1994), comprising caregivers and clients in conjunction with internal and external tools, which enables clients to function with increased levels of independence from direct, one-on-one caregiver support.

2. The Living and Working Situations for Individuals with Disabilities

Over the past few years, we have been working in collaboration with local assistive technology specialists from the Boulder Valley School District (BVSD 2004) and Imagine! (Imagine! 2004), a community-based, assisted living, non-profit organization. Through a number of site visits and informal interviews with parents, teachers, and assistive technology specialists from BVSD, as well as clients, direct care providers and supervisors from Imagine!, we were able to gain an understanding of the everyday working and living activities of individuals with disabilities. In addition, we studied the use of existing technologies that attempt to support this community. Finally, we launched a set of presentations/focus groups to explore design possibilities and user concerns. We now briefly describe some of the findings, highlighting current situations and existing technologies.

2.1 Living

Since the 1970s, individuals with moderate to severe cognitive disabilities have increasingly migrated from large institutional settings to smaller group home settings (Braddock 2002). Those who are not in group homes often live with their families. As a result, many individuals with cognitive disabilities have become increasingly integrated into the mainstream, including public schools and workplace settings. Movement into group homes has enabled these individuals to lead more normal lives, but it still prevents most from reaching their full potentials. Many group home residents are capable of completing numerous day-to-day tasks; however, they require constant reminders of the tasks that need to be performed as well as the steps involved. 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 clients as they complete basic tasks, thereby limiting true independence. Unfortunately, often due to budgetary limitations, it is easier and sometimes 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 to guide each of them through the process.

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. 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 those with the severest disabilities and allows little time to pursue personal interests. This model limits independence and self-determination while fostering continued dependence on group home service providers. In this environment, a client's activity and meal choices are limited by the other clients in the home and ratio of clients to service providers. The clients typically only participate in community activities as a group and often the lowest-functioning person in the group limits the community activity choices.

2.2 Working

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 the benefit of only minimally increased self-esteem to participants because they have jobs of their own. These opportunities provide little freedom to the individual to pursue a job of personal interest and little or no contact with the outside community.

Those with less severe needs may work in a variety of employment settings in the community and perform a range of jobs, such as bagging groceries, janitorial work, or bussing tables. Traditional models for helping clients attain employment have heavily depended on the service of job coaches. Schools and public and private adult services programs locate companies willing to hire individuals with cognitive disabilities and identify the jobs at those companies suitable for individuals with different sorts of disabilities. Students and clients are then matched with job coaches who work with them to uncover their career interests and skill levels, and who may begin to teach their clients specific job skills in isolation. For example, if the person desires to work in a fast food restaurant, they may already know generally how to clean tables and empty the trash, but may not know how to fill a napkin dispenser or how to mop a floor. Because a fast food restaurant must be open many hours there is little opportunity to teach the person the general skills in the specific environment, thus they must be learned at school or a training center.

When the client begins work, the job coach stands nearby and prompts the client through each step, showing where to find the mop, demonstrating how to fill the bucket, reminding the client to get the corners but to skip any areas where people are currently dining. The job coach tries to fade such prompts as quickly as possible. For some clients, the job coach may be able to begin fading within the first day, but for others it may take weeks or months, or it may never happen at all. The job coach will also teach the client about the social graces that must be followed, such as waiting to fill the dispensers until there is no one there, or saying “excuse me” if the client bumps into someone. Eventually, the job coach will want to fade completely from the work environment and check in with the client’s employer only periodically. At this point co-workers may naturally pick up some of the job coach’s roles, such as providing reminders when the break is over, but the client is primarily on his or her own. The job coach becomes involved again only if a problem develops or a new skill is needed; otherwise, the job coach is busy coaching new clients and monitoring others.

When a client is unable to learn job tasks without the assistance of a job coach, external aides such as pictures may be used as reminders of the higher-level tasks that must be completed. If there are specific skills the client is unable to master, the job coach may meet with the employer and *retool* the job so that the client can be successful. For example, if a client cannot physically toss a large bag of garbage into a tall garbage bin, that client may be exempt from emptying the garbage and may instead take on the duty of cleaning the restrooms. When the client remains unable to do the job independently after all possibilities are exhausted, the services agency may decide that the client either must move to a different and possibly less rewarding job that is simpler or move into a non-integrated supervised work environment.

2.3 Previous Developments to Facilitate Living and Working Independences

A PC-based prompting and scheduling tool titled the VISIONS System (Baesman and Baesman 2003) uses stationary touch screens distributed throughout the house to provide prompts that aid in the performance of simple domestic tasks such as cooking. VISIONS is an immobile system; it is housebound, and therefore activities taking place outside of the home are beyond its computational support. To address this problem, a collection of picture cards are used to assist such away-from-the-system tasks as grocery shopping.

Acknowledging the limitations of housebound systems, AbleLink Technologies (Davies 2004) developed a line of PDA-based prompting systems that are direct descendants of VISIONS. These include the Pocket Coach and Picture Coach (Davies and Stock 1996), which provide audio and visual prompting, respectively and Visual Assistant (Davies et al. 2002), which integrates audio and visual prompts to provide multi-model support.

Visual Assistant has three modes of operation: “play only,” “play/done,” and “to do list.” In the “play only” mode the client can step through the script in a linear fashion by pressing a button as each task step is completed. The “play/done” mode is similar to "play only" except an additional button is added that allows the client to explicitly signify they are "done" with the step; the "play" button is used to repeat the instructions for the current step. In the "to do list" mode, the client can *cycle* through the task steps by using the "play" button. In this mode, the "done" button is used to remove a step from the cycle. These different modes provide some nuanced interaction options for different types of clients and tasks. This system has provided an effective solution for basic task support.

Both the VISIONS and AbleLink systems are based on a similar model that is divided into two phases: *planning* and *action.* During the planning stage, the caregiver, often in conjunction with the client, plans an activity by creating a script. Later, the client executes the script when support is needed during the action phase. This model is limited because the planning is based on some envisioned context, while the action takes place in an actual context that may not coincide with the envisioned context. Once the planning phase is complete, the client is left with a *closed system* that cannot react to dynamic situations.

Jönsson and Svensk (1995) performed much of the early exploration of personal digital assistants (PDAs) for people with cognitive disabilities with their development of the Isaac system (Isaac 2004). From the earliest stages they acknowledged the need to integrate human agents into the system and therefore provide support for situated action (Suchman 1987), in which problem solving takes place in the context of action. In order to provide such support, the caregiver, or human agent, needs to have an awareness of the client's context that is sufficient to understand and solve problems in an *ad hoc* manner. Error recovery is implemented by integrating a human agent into the system to reassure and assist the client through equipping the device with a camera and cell phone to send images and describe the problem context to a remote caregiver. 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.

2.4 Summary of Current Living, Working and Support Environments

The situations in which clients live and work highlight a unique set of parameters that can be used to guide the design of socio-technical support systems. From our examination of current work and living conditions, we have seen that independence is something that is valued by most parents, teachers, and the community, as well as the clients themselves. Although clients may have sufficient skills to complete a large variety of tasks, they are often unable to remember how to chain these skills to complete a task (e.g., they may know how to use a microwave, know how to use a can opener, and which can of soup is their favorite, but they may not be able to tie these together when asked to make soup).

Existing task support systems, while providing real support and making actual changes in the lives of clients and caregivers, do not provide sufficient support for script creation and configuration. This has led to adoption problems in both the VISIONS and AbleLink systems. In addition to making a system that is easy to configure and use, caregivers expressed repeated concerns about the inherent reliability of complex technical systems. The risk becomes much higher if the system fails when a client is in a situation that can be managed only with the leverage provided by the system. We have seen that human job coaches providing situated prompting is a “tried and true” training technique that allows many people to do things that they are otherwise unable to do. However, the prevailing model of distinct planning and action phases seen in current computational prompting systems is limited to simple tasks in well-constrained environments.

As tasks and environments become more dynamic, support for situated action (Suchman 1987) is required. This analysis has led to some basic principles to be considered in the design of socio-technical task support systems for clients and caregivers:

- To facilitate adoption and reduce eventual abandonment, caregiver interfaces need to be first-class objects (i.e., the caregiver’s configuration interface is as important as the client’s use-time interface).
- To address safety concerns, the design needs to focus on robustness, and more important, to make caregivers an integral component of the system during use-time.
- To support situated action in dynamic environments, error detection and correction are required, which may include both system and caregiver intervention.

2.5 Task Completion as Distributed, Coordinated Work by Caregivers and Clients

The unique characteristics of the environments discussed above pose great challenges to our current understanding of how innovative technologies can support distributed and tightly integrated work activities. The prompting systems described in section 2.3 create a level of distributed cognition that helps a client to complete a task. The knowledge needed to complete a task in some preconceived situation is transferred to the prompting device by the caregiver, which is later used as a cognitive artifact by the client in performing the task. The cognition is distributed among caregiver, client, and artifacts across space and time, but distribution is dichotomized into distinct planning and action phases. To overcome this dichotomy, we explored more interactive collaborative work practices.

In the following section, we explore existing distributed and cooperative group configurations that might inform design decisions in the context of our analysis of current job-coaching approaches (as described in section 2.2). In doing so, we integrate and expand an existing approach by exploring the distributed and coordinated nature of the activities that clients and caregivers perform when they carry out work tasks. In contrast to current approaches for distributed work practices, we found a unique aspect of our context—namely, that its primary goal focuses on supporting certain individual tasks as opposed to the traditional group endeavors in which the primary goal is to create a final *common* tangible object or outcome. Next, we briefly outline some of the important aspects of existing work configurations that have informed and inspired the approach we put forth in this paper.

3. 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 socio-technical 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: Work configurations and active distributed support systems: Comparing and contrasting main characteristics

	Project Teams	**NetWORK**	**Knotworking**	**Active Distributed Support Systems**
How do they come into existence?	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	The need or requirement for external support due to the complexity of the task at hand (e.g., landing an airplane)
Working conditions	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	Well-defined and bound tasks – different goals among those involved
Established roles	Work assignments – Teams often follow the traditional organizational chart, and most of the time 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"	Unidirectional relation between those who support a task and those who are supported in order to accomplish the task
Duration	Determined by the work assignment	Short-term projects, but long-term relationships	Specific activities that are often short-lived but repetitive	Tasks are often short-lived but interactions are continuous without a necessary endpoint
What holds them together?	Work assignment	Social relationships	Well-defined practices	Need for support
Major challenges	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	Communication, coordination, context awareness, intersubjectivity, temporal and spatial alignment, error detection and correction
Technological support	Shared calendars, organizational memories	Communication tools, and organization memories	Shared calendars	Mobile and ubiquitous systems: PDA prompter, GPS and other sensor technologies
Example domains	Assembly-line work	Knowledge workers	Flight crews and surgical teams	Air-traffic control, caregivers support for individuals with disabilities or elderly

We have looked into existing work configurations in search of inspirations and insights to help us in the design of a socio-technical system with the goal of improving the work opportunities and conditions of those with cognitive disabilities. In designing a socio-technical system we were interested in not only the technologies for supporting the work of these individuals, but also creating social conditions whereby clients and caregivers can coordinate their work activities through the use of such technologies. In the CSCW literature, one can find extensive descriptions and discussions on different

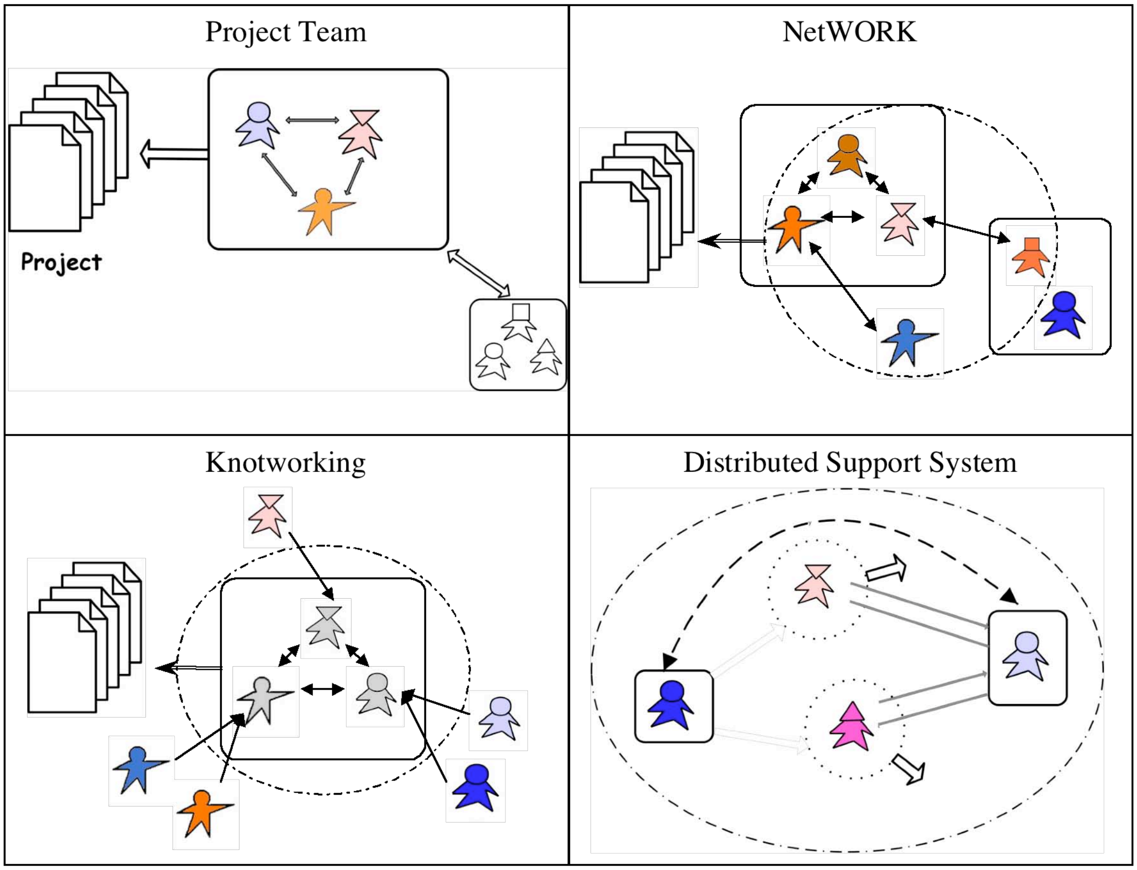

Figure 1: Work configuration diagrams

This figure contrasts the traditional project team, Knotworking, and NetWORK configurations with the distributed support system configuration, highlighting that the former configurations focus on a common final product or outcome whereas the latter focuses on supporting specific tasks and goals of individuals with cognitive disabilities.

work configurations; in particular, three approaches are of interest to our research (see Table 1). Each of these configurations offers different affordances to allow as well as restrict different work activities. As such, they can be regarded as different *task support systems*, which create conditions for the work to be accomplished. These group configurations provide the necessary backdrop for an in-depth understanding of the issues and nuances concerning social interactions and norms, the nature of practices, challenges, and potential technical support.

3.1 Project Team

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 involve long-term relationships, clearly defined social norms, and shared background and knowledge. To achieve their common 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.

3.2 NetWORK

In the recent network society (Castells 1996), new forms of social structures are emerging in work environments to attend to the demand for a more flexible, dynamic, and distributed nature of work practices as well as the complexity of the problems that workers attempt to tackle. 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 (Nardi et al. 2002)]. 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 these networks.

3.3 Knotworking

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. (1999) 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.

3.4 Important Aspects of Existing Work Configurations

Table 1 summarizes the aforementioned work configurations. 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 with 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 four diagrams in Figure 1 convey the major elements that differentiate the work configurations: who does the work (focusing on the relationships among workers), what the roles are and how they are assigned, and what the driven forces (or goals) of the work activity are. Roles are presented as "gray." The rectangles are the formal boundaries of formal organizations of teams, whereas the dashed circles are the boundaries of the systems (e.g., social networks) created to enable the work to be done. The thick arrows represent the goals of the work activities, or the direction that drives workers' actions. 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 boundaries of *project teams* define the roles and people who will work together toward the organizational goals. In an *active distributed support system*, 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.

In light of the previous analyses and the aforementioned job coaching approach, we saw the need to extend these approaches to provide a more effective and scalable means for clients as well as caregivers to carry out their respective work activities. By incorporating some ideas from the work configurations into the design of an innovative socio-technical system in the context of job coaching, we proposed a novel model, the active distributed support system model, which is the object of our research. Table 1 compares the work configurations with this model. 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. This model integrates innovative mobile and ubiquitous technologies and new forms of job monitoring and assistance made possible by these technologies. We believe that this approach provides new opportunities for clients and caregivers by allowing a larger number of individuals with greater range of cognitive abilities to work and by allowing caregivers to attend to a larger number of individuals. The rest of this paper further explores the characteristics and challenges of implementing this work organization.

4. Active Distributed Support Systems

Guided by the distributed cognition framework (Salomon 1993), discussions with domain experts, and surveys of existing technologies for increased independence, we have developed two coupled prototypes: the Memory Aiding Prompting System (MAPS), which includes caregiver authoring and client prompting tools; and Lifeline, which provides support services for MAPS and remote monitoring tools for caregivers. The combination of these two systems enables active distributed task support, hereinafter referred to as MAPS-Lifeline.

The major aspect of the *active distributed support model* that significantly differs from the previous work configurations involves 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 can be 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 and airplane pilots (and navigators), has no "product"; the measurement it is using is safety and timeliness of the whole system. The goal is the dynamic balancing of the requirements over time.

The model of collaboration that is the basis for our work was built on an analysis of existing task support systems (described in section 2.3). It differs from the work configurations presented in section 3 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 (1999) define *information ecology* as "a system of people, practices, values and technologies in a particular local environment." They describe characteristics of such a system that include *system, diversity*, *co-evolution*, and *locality*. Figure 2 shows how the MAPS and Lifeline applications function together as a *system*. *Diversity* exists as the complementary needs and offerings of the caregiver and client. 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, and 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. To accomplish this oblique strategy, we use the concept of *symmetry of ignorance* (Fischer et al. 2002). 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 example of the consequences of ignoring the demands of this symmetry is the design of airline reservations systems, as described by Landauer (1995, pp. 164-165). 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. Conversely, 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.

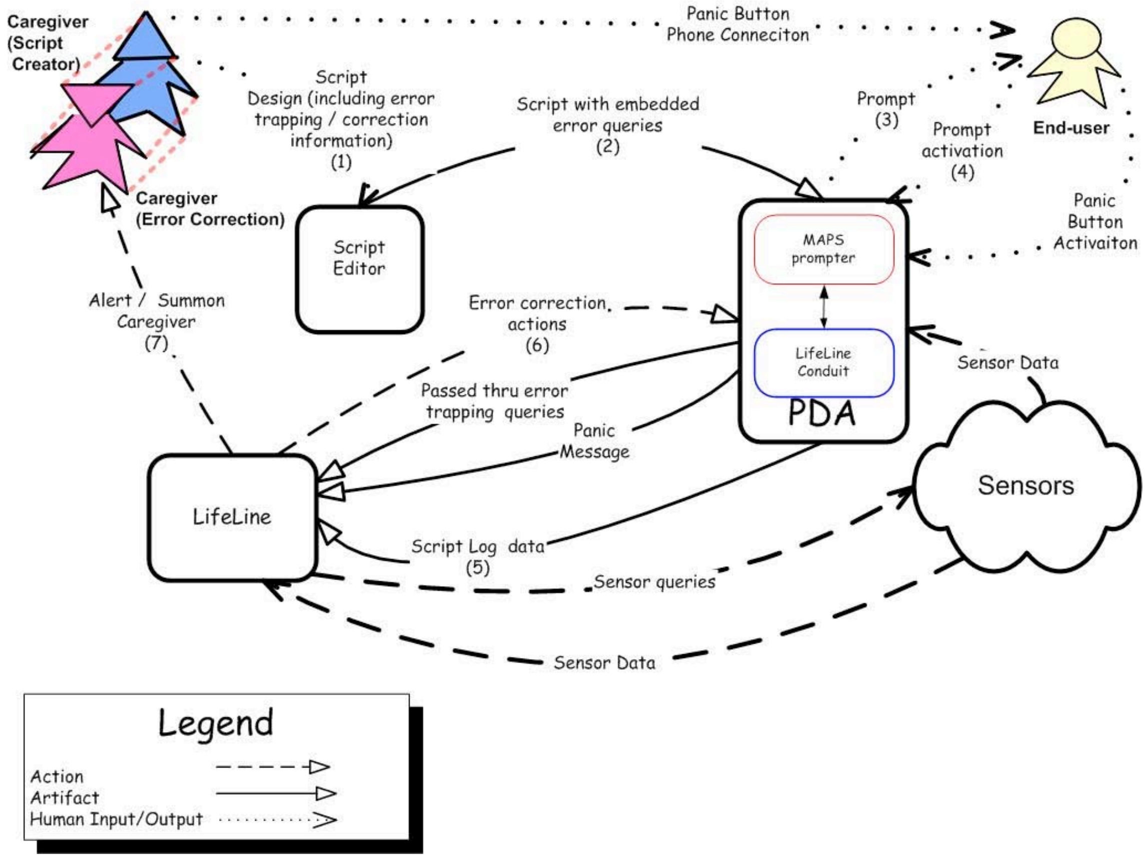

Figure 2: A Conceptual diagram of MAPS-Lifeline

5. Designing and Developing Active Distributed Support Systems: MAPS-Lifeline Design

Initial attempts at technical solutions to provide individuals with task supports are promising and provide much of the inspiration for our work. They do not, however, support 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.

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 or job coach will still need to teach the client how to complete the task by using the MAPS prompter but because of the prompter the job coach will be able to fade more quickly. The caregiver is responsible for ensuring successful task completion and soon 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

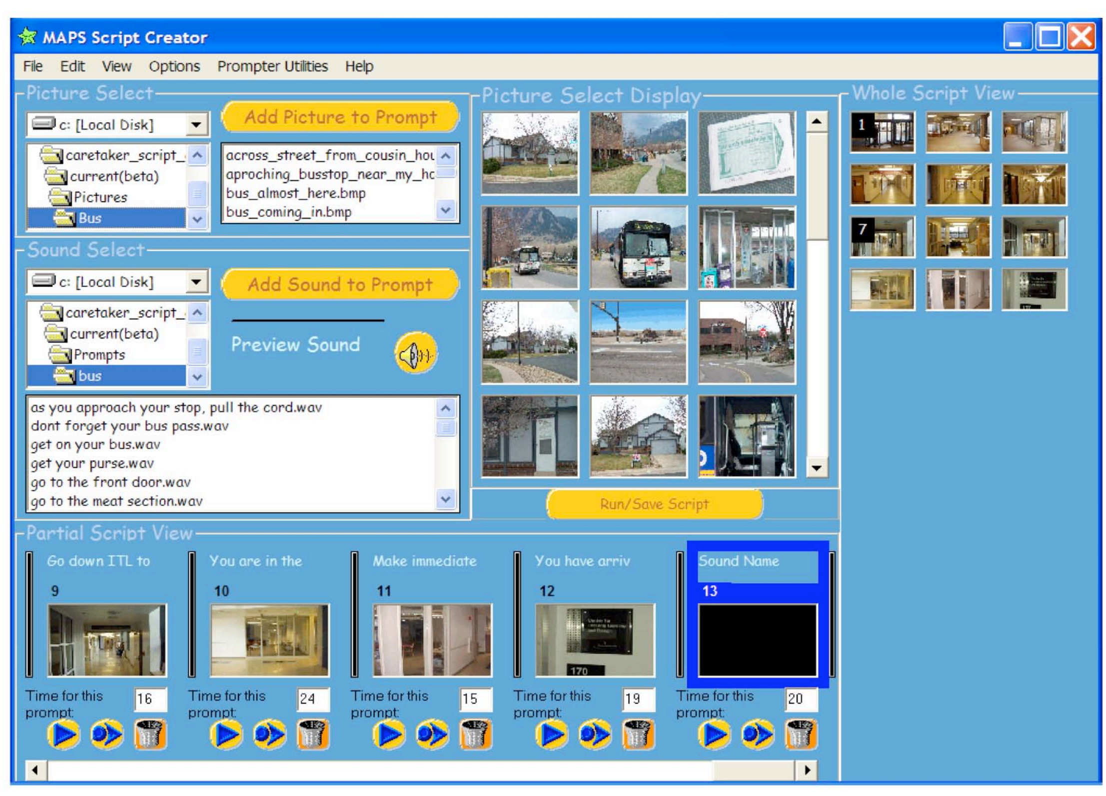

Figure 3: The MAPS script editor

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 an example of a homeostatic system, by which we mean that its design supports a process and is not structured to produce a product. There is no artifact (like a document or a software program) that is necessarily the result of the system. Instead, the goal is to meet the needs of both the user with cognitive disabilities and the caregiver. As such, it is the dynamic balancing of their needs that is the result. This system is based upon context (i.e., the environment, the plan, and the task) 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.

Through this approach, the power of distributed cognition is leveraged in context-aware socio-technical systems that integrate ubiquitous computational and human support for guided situated action (Suchman 1987). Our prototype demonstrates the technical feasibility of creating a remote support system, but it does not address the real question of whether such a system can effectively be used by caregivers and travelers to cooperatively accomplish tasks.

5.1 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 MAPS-Lifeline system uses a dynamic, multi-tiered approach to error detection and intervention. In this approach, the intervention strategy is based on client and error characteristics (Carmien 2003). 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. 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 in which each stakeholder gets precisely what is needed at the time and in the fashion that is required to extract maximum user benefit.

Lifeline allows caregivers to remotely and unobtrusively monitor a worker's activities and offer assistance when needed. Figure 5 shows the flow of information as a client performs a work task that requires indoor navigation (e.g., mail delivery in a complex building). When the script is executed on the handheld device it is registered with Lifeline. As a result, Lifeline will expect a certain sequence of steps. Associated with each step are constraints that define abnormal conditions (e.g., time limits or locational boundaries). As the script is executed, status changes are sent to Lifeline, which continuously displays the current script description, the list of steps in the script with expected and actual times, and the worker's location.

Initial discussions with caregivers showed optimism about the potential of mobile prompting systems and the prospect of increased independence for clients; however, their optimism was tempered by a significant concern about safety (Lewis and Norman 1986). "What happens when it breaks?" and "What if they leave it on the bus?" are common concerns raised by caregivers. To address the problem of caregiver trust, we explore the concept of breakdowns (Fischer 1994), which are system or user errors that require intervention. The detection of breakdown states is complex, and can arise from one or more events and sources, including the traveler, the wireless environment, or ubiquitous networked sensors. In the current prototype, we employ two simple methods for signifying or detecting breakdowns. Workers can signal a breakdown and summon caregiver assistance with a "panic button" if they feel something is wrong. Unfortunately, the clients may not always be aware that they have a problem or are off track. Lifeline can detect simple breakdowns such as when task steps exceed an expected time threshold as defined using the script editor or when the handheld device stops sending status data to the server. In these cases the caregiver is notified via a Simple Message Service (SMS) and can then explore the nature of the breakdown.

5.2 Robustness and Fail-Safe Considerations

To address the safety and accountability concerns that were raised by caregivers during informal interviews, we identified the following vulnerabilities associated with the geographical separation created by a client's increased mobility.

First, there is a concern with script errors, either due to user actions (e.g., accidentally cueing an image/sound prompt out of correct sequence) or unexpected environmental conditions (e.g. the bus the client is on has to take a detour due to construction). MAPS-Lifeline implements error detection by using a combination of internal state monitoring and sensor technologies. While scripts are running, audio and

Figure 4: The MAPS prompter

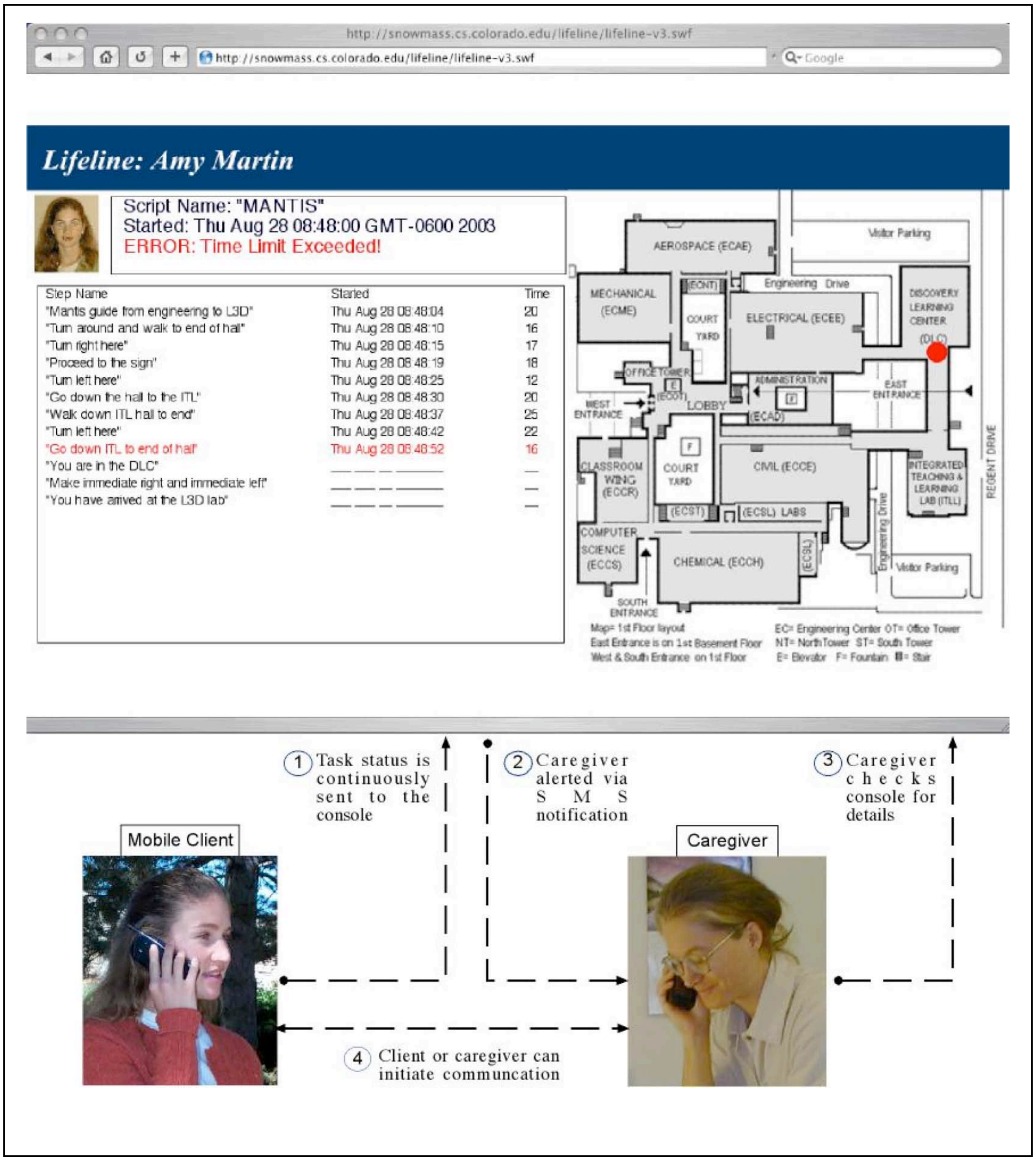

Figure 5: The Lifeline prototype

visual prompts are combined with timing and sequence constraints. These constraints are used to determine if the user is “off track.” In addition to simple time limit thresholds, Lifeline can use real-world telemetry data such as GPS and other sensor data [e.g., see MANTIS (Han 2003)] so it can compare the expectations defined by the script with actual events.

Second, caregivers expressed concerns about the wireless connectivity being a weak link in the system. To address this concern, we implemented two fail-safe strategies. On the MAPS handheld, redundant wireless connectivity methods (i.e., Wi-Fi and PPP dialup) are used. Polling algorithms are used in Lifeline, which has a more stable wired TCP-IP connection, to test connectivity. Lifeline will send an SMS message to the caregiver if the connection with the handheld is broken and cannot be reestablished within some user defined time threshold. The currently implemented strategies provide a functioning safety net; however, we acknowledge that this is just the beginning and expect that the need for more sophisticated methods will be identified during more thorough testing.

5.3 Current Prototype Implementation

The MAPS prototype is currently deployed on an iPAQ Pocket PC[1] running the WINCE operating system (see Figure 4). It is written in embedded Visual Basic (EVB) and uses a Sybase Adaptive Server Anywhere database to store and access task scripts that include audio-visual binary data as well as script 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. It utilizes the Flash Communication Server, which provides a framework supporting synchronous communication. There are three main components to Lifeline: (1) a *conduit*, which runs on the MAPS prompter and enables communication with the server; (2) a *server*, which receives status information, detects potential problems, and notifies caregivers when necessary; and (3) a *console*, which allows caregivers to see details of the client's activities. The conduit is responsible for reading streaming log data generated by MAPS. It then creates and maintains a Remote Shared Object on the Flash Communication Server. The server traps errors (described above) and sends SMS messages to caregivers via a common gateway interface (CGI) script on an http server. The console allows caregivers to view a client's status from any web browser. The console displays the client's current status, including current task, step, and location. It also highlights steps where errors occurred (e.g., timeout or panic messages).

5.4 Illustrative Scenario

The prototypes we have implemented demonstrate our approach for an active distributed support system. 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,

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

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 for others, 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 because 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 reminded 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.

6. Discussion and Future Work

In the above scenario MAPS-Lifeline serves as a cognitive aid, supporting diminished executive and memory functions. Some clients might continue to use it in this way, never learning to work without the aid, whereas others will learn to perform tasks to the point where the aid is no longer needed. A client trained under a traditional model walks through the task steps with the caregiver. When the caregiver feels the client has learned the task, the caregiver covertly observes the client during task performance. After a predetermined number of successful task executions, as set by the caregiver, the client is "certified" and is allowed to perform that task without supervision (Fischer and Sullivan 2002). 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 distinctions 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 clients may perceive that they are acting without human supervision.

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 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 [*Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition (APA 1994) 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. We used video analysis during usability testing and discovered several issues, which can be grouped into two broad categories: bugs that were revealed during unexpected usage patterns; and UI complexities that were created by poor design choices [e.g., forcing the user to be cognizant of editor modality (Norman 1990)]. In the former category, we enforced appropriate constraints that prevented users from generating invalid SQL queries. In the latter category, we made modal changes implicitly driven by user activity rather than requiring the user to explicitly (and possibly incorrectly) choosing a mode of operation. Both of these techniques are similar ways of imposing constraints that prevent users from committing errors (Lewis and Norman 1986). After several iterations, our current application reflects the needs and limitations of the target population, in this case moderately computer literate adult caregivers of cognitively challenged family members.

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 (Han 2003). 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 MANTIS 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). We are also leveraging our work with other groups whose projects focus on the accessibility and navigation of public transportation (Fischer and Sullivan 2002).

7. Conclusion

We have shown a few of innovative ubiquitous and mobile technologies tightly integrated with a work configuration and tasks for those with cognitive disabilities. This approach has the potential to help provide more independent and fulfilling lives for people in this community. We believe that integrating the active distributed support system framework with user-centered design approaches will help researchers and practitioners to implement ubiquitous and mobile applications that are indeed usable and useful for real users dealing with real-life problems. We also believe that the CSCW community has much to learn from the disabilities community as it highlights situations that we often take for granted in our everyday interactions with the world. The complexity of everyday situations that are revealed by studying the lives of clients and caregivers, with the complex and distributed interactions in the social and physical environments, will create a broader understanding of how humans in general interact in the world. As we develop this work, we hope that it will inform the design of more usable and useful cooperative and coordinated environments for all.

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