H. Gellersen et al. (eds.), ECSCW 2005: Proceedings of the Ninth European Conference on Computer-Supported Cooperative Work, 18-22 September 2005, Paris, France, 65–82.
© 2005 *Springer. Printed in the Netherlands.*

A Groupware Design Framework for Loosely Coupled Workgroups

David Pinelle and Carl Gutwin
Department of Computer Science, University of Saskatchewan, Canada
david.pinelle@usask.ca, carl.gutwin@usask.ca

Abstract. Loosely coupled workgroups – where workers are autonomous and weakly interdependent – are common in the real world. They have patterns of work and collaboration that distinguish them from other types of groups, and groupware systems that are designed to support loose coupling must address these differences. However, loosely coupled groups have not been studied in detail in CSCW, and the design process for these groups is currently underspecified. This forces designers to start from scratch each time they develop a system for loosely coupled groups, and they must approach new work settings with little information about how work practices are organized. In this paper, we present a design framework to improve the groupware design process for loosely coupled workgroups. The framework was developed to provide designers with a better understanding of how groupware systems can be designed to support loosely coupled work practices. It is based on information from CSCW and organizational research, and on real-world design experiences with one type of loosely coupled group—home care treatment teams. The framework was used to develop Mohoc, a groupware system for home care, and the system and underlying framework were evaluated during two field trials.

Introduction

Loosely coupled workgroups are common in the real world, and they have been identified in a number of domains including education, healthcare, knowledge work, and mobile service work (Hasenfeld 1983; Pinelle 2004). Workers in these groups are weakly dependent on one another and can function autonomously, often without the need for immediate clarification or negotiation with others (Olson and Teasley 1996). They have patterns of work and collaboration that

distinguish them from other types of groups, and groupware systems that are designed to support loose coupling must address these differences. However, they have not been studied in detail in CSCW, and it is not clear what their design requirements are, or how groupware should be developed to address their needs.

Groupware design for loosely coupled workgroups is underspecified, and groupware designers must start from scratch when they develop a system for one of these groups. Designers cannot make use of others' design experiences in similar groups, and must approach the work setting with little information about how work practices are organized. This makes it easy to overlook important work characteristics that are relevant to design, often leading to systems that are not well-suited for supporting work in context.

In this paper, we present a design framework to improve the groupware design process for loosely coupled groups. The framework has two main parts: a contextual model that describes loose coupling in the workplace, and a set of design approaches for developing groupware applications that support loosely coupled work practices. The design framework is based on information from CSCW and organizational research, and on real-world design experiences with one type of loosely coupled workgroup—home care treatment teams in Saskatoon Health Region (SHR).

The framework was used to develop Mohoc, a groupware system that supports loosely coupled work practices in home care. The Mohoc system supports current home care workflows, including managing clinical documentation, planning treatments, and scheduling appointments with patients. It emphasizes autonomous work activities, but also provides opportunities for workers to collaborate and share information using low-cost communication and coordination features.

The framework was evaluated during two field trials where home care treatment teams in SHR used the system to support the services they provided to shared patients. Results were analyzed to determine how well the design framework performed in the design process. The results suggest that the framework was able to fill its role in specializing the general CSCW design process for loosely coupled groups by adding consideration for work and collaboration patterns that are seen in loosely coupled settings. However, further research is needed to determine whether these findings generalize to other loosely coupled workgroups.

In the next section, we provide a brief discussion of literature on loose coupling and groupware design. We provide a brief overview of the home care work context, and then we present the framework. We then describe how the framework was used to develop the Mohoc groupware system, and present the results of two field trials in SHR.

Loose coupling and groupware design

Organizational research from management, organization science, healthcare, education, and sociology has the potential to help inform the design of CSCW applications. Studies from these areas can help improve the analysis of target work settings and can help to identify important organizational patterns that are relevant to system design, but that are otherwise easily overlooked.

In this research, we used organizational research literature to help build a framework for groupware design for loosely coupled workgroups.

In organizational research, the term "loose coupling" is used to describe relationships between elements in social systems. These elements can be people or organizational units, such as groups, departments, or divisions. Weick (1976) describes loose coupling in education:

> By loose coupling, the author intends to convey the image that coupled events are responsive, but that each event also preserves its own identity and some evidence of its physical or logical separateness. Thus, in the case of an educational organization, it may be the case that the counselor's office is loosely coupled to the principal's office. The image is that the principal and the counselor are somehow attached, but that each retains some identity and separateness and that their attachment may be circumscribed, infrequent, weak in its mutual affects, unimportant, and/or slow to respond. Each of those connotations would be conveyed if the qualifier loosely were attached to the word coupled. Loose coupling also carries connotations of impermanence, dissolvability, and tacitness all of which are potentially crucial properties of the 'glue' that holds organizations together. (p. 3)

In a later paper, Orton and Weick (1990) formulate a more precise definition of loose coupling. They argue against using what they describe as a unidimensional interpretation of loose coupling that views loose and tight coupling as opposite extremes along a scale. In this view, "tightly coupled systems are portrayed as having responsive components that do not act independently, whereas loosely coupled systems are portrayed as having independent components that do not act responsively" (p. 205). Orton and Weick advocate using a dialectical interpretation of loose coupling that describes system elements according to their distinctiveness and responsiveness. Elements are distinctive if they are well-defined and semi-autonomous, and elements are responsive if they react to the actions of other elements in the system:

> If there is neither responsiveness nor distinctiveness, the system is not really a system, and it can be defined as a noncoupled system. If there is responsiveness without distinctiveness, the system is tightly coupled. If there is distinctiveness without responsiveness, the system is decoupled. If there is both distinctiveness and responsiveness, the system is loosely coupled. (p. 205)

In CSCW literature, loose coupling in the workplace has been discussed as a potential design dimension, but not in detail. In a discussion of organizational structure in research and development (R&D) work, Grinter et al. (1999) show that organizations adopt different coupling patterns depending on work interdependencies and on the physical relationships of workers and workgroups. They equate co-location with tight coupling and high communication requirements, and physical distribution with loose coupling and reduced communication requirements.

Olson and Teasley (1996) describe loose and tight coupling in design teams at an automotive manufacturer using two work dimensions: the required response time, and the required level of interaction between collaborators. They state that in tightly coupled work, workers are directly dependent on each other, and immediate interaction is needed to coordinate work. In loosely coupled work, "people need to be aware of others' activity and decisions, but without the need for immediate clarification or negotiation. The work can proceed in parallel." (p. 422)

Churchill and Wakeford (2001) suggest that the level of coupling in mobile groups can be used as a design dimension for technologies to support mobile collaborators. They describe two coupling styles for mobile workers: tight mobility and loose mobility. In tight mobility, mobile

collaborators need real-time synchrony with others in order to communicate and coordinate work. In loose mobility, mobile workers asynchronously access documents or information – while they still co-operate with others, the collaborative requirements are reduced. Loose mobility, then, represents a form of loosely coupled interaction specific to mobile groups. It implies that workers are not regularly synchronized with others, and that asynchrony serves an important role in information sharing between workers.

In previous work, we discussed loosely coupled work patterns in home care treatment teams, and presented a preliminary set of design principles for developing groupware applications for loosely coupled collaborators (Pinelle and Gutwin 2003). We discussed the discretionary nature of collaboration in loosely coupled work, and the preference workers had for low-cost collaboration such as low-level awareness and asynchronous communication instead of synchronous communication, which required significant effort to initiate. From an analysis of home care work, we proposed several groupware design strategies, including: preserving workers' flexibility in managing their workdays, consolidating fragmented information repositories that are maintained by the workers, and supporting low cost communication and coordination.

In this paper, we build on our past work on loose coupling (Pinelle and Gutwin 2003). We present a formal design framework that is partially based on our work in home care, but that also incorporates findings from related studies of loosely coupled work from organizational research. The framework describes common work and collaboration patterns seen in loosely coupled settings, and it also provides a set of groupware design approaches that significantly expands on those that we previously presented.

Setting

This research was carried out as part of a project to develop a groupware system to support collaboration in home care treatment teams in Saskatoon Health Region (SHR) in Saskatchewan, Canada. The design framework grew out of design work in home care and was developed for three reasons:

- Current CSCW studies provided limited guidance on designing groupware for the setting.
- Current groupware systems did not adequately address the needs of the workers. For example, groupware systems such as instant messaging, shared calendars, newsgroups, and existing workflow systems did not provide adequate support for teamwork, taskwork, autonomy, and flexibility.
- There were extensive studies on loose coupling in organizational research fields that characterized home care work practice and that had the potential to provide guidance in analysis and design for loose coupling in general (e.g. Orton and Weick 1990; Scott 1985; Hasenfield 1983).

Initial observations and interviews with workers in the home care setting contributed to the development of the framework. The framework was later used in the design of Mohoc, a clinical information system for home care, and it was evaluated during two field trials where Mohoc was

deployed for a combined total of 6 months. The SHR home care setting is described in more detail elsewhere (Pinelle and Gutwin 2003; Pinelle 2004). We provide a brief overview here.

Patients who receive home care services in SHR are treated in their homes by clinicians from several disciplines. The set of community-based workers who share a common patient are called a home care treatment team, and teams can include members from as many as seven different disciplines, including occupational therapists, physical therapists, nurses, dieticians, social workers, case managers, and home health aides. Since each worker treats multiple patients during a workday (usually 6-15 depending on the discipline), and since teams are formed around patients, each worker is a member of multiple teams.

Regardless of the discipline, home care workers spend most of their time carrying out a limited number of tasks. Most of their time is spend planning their workday, visiting patients, driving between patients' homes, and filling out paperwork. With the exception of home health aides, workers have significant discretion in carrying out their daily activities, and managers act primarily in advisory roles.

Treatment teams members work together in a loosely coupled fashion. Since team members share a common patient, their work is interdependent. However, work practice is not organized to facilitate interaction within teams, so collaboration is infrequent. Workers are mobile, maintain different schedules, and work out of different locations. This often makes it difficult for them to determine others' locations and availabilities, and it can require significant effort for them to initiate contact with others. Workers may occasionally see each other in their offices, but these meetings are often sporadic since there are no fixed office hours, and since some disciplines begin visiting patients earlier than others. Each discipline maintains a separate set of paperwork for each patient, and this paperwork is carried with workers in the field so that they can access it at the point of care. This makes paperwork unavailable to team members from other disciplines, even though the content is potentially valuable.

In multidisciplinary teams, each worker is recognized as the expert in their discipline's practice domain, and it is acknowledged by others that they are the best suited to make decisions that fall within that area. This professionalism and knowledge specialization effectively partitions the work that takes place in home care since each worker is usually able to focus on their separate concerns and leave other areas to workers from other disciplines.

Even though collaboration and information sharing can be difficult, the reduced interdependence seen in home care has some benefits. For example, the mobile work environment seen in home care is unpredictable—workers may be delayed while driving between patients' homes or while delivering treatments. Loose coupling gives workers the flexibility that they need to handle this uncertainty since they do not need to consult others when plans and schedules need to be revised.

Design Framework

The design framework was developed by synthesizing existing information on loose coupling in CSCW and organizational research. It was also based on observations and interviews with home care workers. These included four rounds of semi-structured interviews, and each round consisted

of 7 one-hour interviews. Each round included an interview with a member of each home care discipline in SHR. In addition, approximately 60 hours of field observations were carried out with workers from each of the disciplines. The data collection and analysis processes are described in further detail in Pinelle and Gutwin (2003).

The framework was developed to help designers consider important characteristics of loosely coupled work practice while designing groupware systems. The framework attempts to improve the design process by:

- clearly defining loose coupling and loosely coupled groups for groupware designers;
- providing a set of concepts that designers can look for when approaching a new work setting;
- providing a description of collaboration patterns, work patterns, reasons, and outcomes seen in loosely coupled workplaces;
- providing a set of approaches for designing groupware systems that are appropriate for work practice in loosely coupled groups.

The framework has two main parts, each of which supports a different step in the design process: a contextual model, and a set of design approaches. The contextual model describes loose coupling in the workplace, and it acts as a theoretical foundation for the rest of the framework. The design approaches provide guidance on developing groupware applications that are tailored to work practices in loosely coupled settings.

Operational Definitions for Loose Coupling

We propose operational definitions for "loose coupling" and "loosely coupled groups." Our goal was to develop definitions with few ambiguities so that designers can identify loose coupling in the workplace.

Defining loose coupling

In this section, we provide definitions for loose and tight coupling in social systems. The definitions are general and can be used to describe relationships between a range of system "elements", which can include organizations, groups, or individuals. The definitions are partially based on definitions by Orton and Weick (1990).

We define loose and tight coupling using three dimensions: interdependence, distinctiveness, and integration. Interdependence describes the strength of linkages between system elements. Interdependence refers to "the extent to which the items or elements upon which work is performed or the work processes themselves are interrelated so that changes in the state of one element affect the state of others" (Scott 1987, p.214). Integration indicates the level of coordination seen in interaction patterns between system elements (Bertrand 1972, pp. 26). Distinctiveness indicates the degree to which elements are well defined and semi-autonomous (Orton and Weick 1990). The definitions follow:

Loose coupling. Loose coupling exists between two or more elements when:

1) *Low interdependence*. Each element's actions affect the other elements weakly and/or infrequently.

2) *High differentiation*. Elements are distinct, logically separate, and self-contained.

3) *Low integration*. Interaction to manage interdependence does not take place regularly between elements.

Tight coupling. Tight coupling exists between two or more elements when:

1) *High interdependence*. Each element's actions affect the other elements significantly and regularly.

2) *Low differentiation*. Elements are not self-contained or distinct.

3) *High integration*. Interaction to manage interdependence takes place regularly between elements.

The differentiation described in these definitions can operate at different levels. For example, when the elements are two people, differentiation can indicate well-defined roles that give a logical separation to the work of each individual. When the elements are groups, high differentiation can indicate separation of function or purpose between the groups.

The low interdependence described in the loose coupling definition indicates that elements' actions will not strongly impact other elements. This is described in detail by Weick (1982):

> Loose coupling exists if A affects B (1) suddenly (rather than continuously), (2) occasionally (rather than constantly), (3) negligibly (rather than significantly), (4) indirectly (rather than directly), and (5) eventually (rather than immediately). Connections may appear suddenly, as in the case of a threshold function; may occur occasionally, as in the case of partial reinforcement; may be negligible, as when there is a damping down of response between A and B due to a constant variable; may be indirect, as when a superintendent can affect a teacher only by first affecting a principal; and may occur eventually, as when there is a lag between legislator voting behavior and response by his or her electorate. (p. 380)

Defining loosely coupled groups

In this section, we propose a definition for "loosely coupled groups." The three criteria for loose coupling (interdependence, differentiation, and integration) provide a basis for developing the definition. However, given differences in work patterns over time and differences in relationships between group members, it can be difficult to classify a group as a "loosely coupled group" in an absolute sense. This type of classification seems most appropriate when loose coupling represents the primary relationship pattern between members of the group, and when the coupling patterns are relatively stable over time. Given this qualifier, occasional and brief shifts to tight coupling do not prevent a group from being "loosely coupled", since work will settle back into a loose pattern. The definitions follow:

Loosely coupled groups. Loosely coupled groups meet the following criteria:

1) *Low interdependence*. Each group member's actions affect the other members weakly and/or infrequently.

2) *High differentiation*. Each group member has a distinct and mutually understood role. Roles may be defined by professional disciplines, job descriptions, skills, knowledge specialization, or through periodic planning.

3) *Low integration*. Members do not interact regularly to manage interdependence.

4) *Stability*. In spite of brief and intermittent shifts in coupling style, the high differentiation—low integration patterns remain stable over time.

Tightly coupled groups. Tightly coupled groups meet the following criteria:

1) *High interdependence*. Each member's actions affect the other members significantly and regularly.

2) *Low differentiation*. Each member may or may not have a distinct role.

3) *High integration*. Members interact regularly to manage interdependence.

4) *Stability*. In spite of brief and intermittent shifts in coupling style, the low differentiation—high integration patterns remain stable over time.

Contextual Model: Understanding Loose Coupling in the Workplace

In order to build groupware that supports loosely coupled work situations, it is first necessary to understand loose coupling in the workplace. In the next sections, we present a "contextual model" for loose coupling that describes common work practices in loosely coupled workgroups. It is based on previous work in organizational research, small group research, and CSCW research, and it has three main parts: a set of reasons for the adoption of loose coupling, a set of outcomes of the adoption of loose coupling, and a description of interaction patterns between loosely coupled collaborators.

Reasons for loose coupling

Several factors can contribute to the adoption of loose coupling in the workplace, and they can occur at different levels—at the organizational level, at the group level, at the interpersonal level, or in the external environment. Common contributing factors include: uncertainty in the work environment that requires rapid adaptation by work units, unpredictable tasks that are difficult for managers to monitor and evaluate, employees that are professionals or that have a high level of knowledge specialization, and barriers that interfere with routine collaboration (e.g. physical distribution, mobility, and schedule variability).

Table I. Summary of reasons for loose coupling

Reasons	
Environmental uncertainty and complexity	The system operates in an uncertain and/or complex environment (Orton and Weick 1990; Scott 1985; Aldrich 1979; Lei et al. 1996; Hasenfield 1983)
Non-routine and unpredictable tasks; ambiguous evaluation criteria	Tasks are not routine and are difficult to plan and predict, and evaluation criteria are unclear and poorly defined (Hasenfeld 1983)
Professionalism; specialized knowledge and expertise	The organization has professional employees; employees have specialized knowledge (Kouzes and Mico 1979; DiTomaso 2001; Scheid-Cook 1990)
Limited opportunities for interaction	Workplace factors interfere with interaction and can include: physical distribution, schedule variability, worker mobility, physical environment constraints, organization / group size and complexity (Olson and Teasley 1996; Bellotti and Bly 1996; Fagrell et al. 2000; Smith 1973; Monane 1967)

Table I summarizes the underlying reasons that can lead to the adoption of loose coupling. While each of the reasons can contribute to loose coupling, causality is not always clear, and in some cases, some conditions may be the result of the adoption of loose coupling (Foster 1983, p. 13).

Outcomes of loose coupling

The adoption of loose coupling impacts the patterns of work and collaboration that are seen in groups and organizations. A common outcome of loose coupling is worker autonomy, which is usually associated with a corresponding weakness in managerial oversight. Loose coupling also allows significant adaptability since each worker and work unit is able to sense and rapidly adjust to their local work environment because their autonomy frees them of the need to consult other individuals or work units when making routine decisions.

Table II summarizes the outcomes associated with the adoption of loose coupling. They are not necessarily good or bad (Firestone 1985, p.5; Weick 1976). Instead, the utility of each outcome depends on the specific circumstances confronted in the work situation (Scott 1987, p. 254).

Table II. Summary of outcomes of loose coupling

Outcomes	
Information buffers	Workers maintain local information repositories (Kmetz 1984)
Autonomy and behavioral discretion	Workers are free to use their own discretion in determining their behavior (Aldrich 1979; Tyler 1987; Perrow 1999)
Sensitivity to environmental stimuli	The system has several distinct “sensors”, so it is sensitive to environmental stimuli (Weick 1976; Staber and Sydow 2002; Brusoni and Prencipe 2001)
Adaptability	Workers are able to adapt to the environments that they encounter locally (Rubin 1979; Horne 1992; Lutz 1982; Scott 1987)
Weak authority structure	Authority structures are limited in their ability to sanction subordinates (Staber and Sydow 2002; Lorsch 1973)

Patterns of interaction in loose coupling

Since interdependence is weak in loose coupling, well-established communication channels may not exist, and when more intense collaboration is needed, it can require significant effort. Since workers are autonomous, they can often exercise their discretion in initiating interactions with others, and weak interdependence can enable them to utilize channels that are slow and sparse (e.g. memos or email rather than face-to-face meetings). Low-cost collaboration mechanisms are generally preferred since work is not usually organized to facilitate regular interactions. We summarize coordination and communication in loosely coupled workplaces in Table III.

Table III. Summary of patterns of interaction in loose coupling

Patterns of interaction	
Coordination	Voluntary rather than directed coordination (Litterer 1965) Low-cost coordination strategies ▪ Unexamined assumptions (Gamoran et al. 2000) ▪ Common socialization (Weick 1980; Hasenfeld 1983) ▪ Mutually understood roles, task partitioning (Hasenfeld 1983; Litterer 1965)

	▪ Adjustment without negotiation (Pinelle and Gutwin 2003)
Communication	Tolerance for low efficiency (Staber and Sydow 2002) Tolerance for "non-rich" media (Daft and Lengel 1986) ▪ Email, text messaging ▪ Memos Can be uneven and indirect (Staber and Sydow 2002; Weick 1982)

Design Approaches

The work patterns seen in loosely coupled workgroups have implications for the way that groupware systems should be designed to support them. Unlike more tightly coupled groups, work is primarily autonomous, and communication and coordination occur less often. These patterns suggest that designs should place more of an emphasis on features that support autonomous work, and should support direct collaboration, but only at the workers' discretion.

Table IV presents a set of design approaches that suggest how groupware systems should be designed to support loosely coupled workgroups. They were developed for settings where loose coupling is seen in the workplace, and where it is not the intent of the designer to change the current coupling style. The design approaches are based on the contextual model and on observations from home care in Saskatoon Health Region.

Each approach is based on loose coupling characteristics in the contextual model and presents a design recommendation that suggests how groupware systems should be designed to support loosely coupled work practice. The approaches emphasize the importance of support for autonomous work, and of support for low-cost communication and coordination mechanisms. For example, some of the approaches highlight the value of using low-cost coordination support such as low-level awareness of others' actions so that workers can coordinate their activities without the need for costly explicit negotiation.

Table IV. Summary of design approaches

Design approach	Description
Support autonomy and flexibility	Support current work practices without tightening interdependence between workers since this can reduce autonomy, professional discretion, and flexibility
buffers	Shift select pieces of information from locally maintained information buffers to a merged repository to help improve coordination and awareness of real-world activities.
Support individual workspaces and discretionary sharing	When information maintained by a worker is shared with the rest of the team, the sharing should be at the worker's discretion so that they can selectively protect information.
Integrate collaboration with features for individual work	Support for collaboration should be integrated with features that support individual work. Collaborative features should be unobtrusive and should not interfere with workers' abilities to utilize other more frequently used features.
Facilitate asynchronous awareness	Support awareness of the activities that others carry out in the groupware system. Awareness representations should persist over time to accommodate varied schedules and autonomous work patterns.
Support loose coordination	Support loose coordination, where minimal effort and minimal direct negotiation is needed by the users.
Support loose communication	Provide support that lowers the amount of effort that is required to initiate communication.

Support shifts to tighter coupling	Support periods of direct interaction and periods of no interaction. Support for tighter coupling can be handled in two ways: support for direct communication within the application and/or support for arranging direct communication in the real world.
Preserve flexible group organization	Allow workers to determine their level of involvement in collaborative situations. They should have the flexibility to determine how involved they want to be in a given group, and involvement levels should be conveyed to others.

Mohoc

We used the contextual model during the analysis of the home care work setting, and then we used the design approaches to develop Mohoc, a groupware application to support loosely coupled work in home care treatment teams. Each design approach is instantiated in user interface and interaction features in the system (see Table V), and Mohoc provided a means of investigating the value of the underlying design framework in the home care context.

The main reason for developing groupware support for home care was to improve information access by workers and to lower the amount of effort needed to communicate and to coordinate tasks within treatment teams. The system was developed to support current autonomous work activities, including: managing clinical documentation, planning treatments, and scheduling visits with patients. It makes information generated through those activities available to other team members so that they can coordinate activities more closely and without the need for direct negotiation.

The Mohoc system is an asynchronous groupware system that uses a client-server architecture. The system was developed to operate using wireless networks (CDPD and 1X) that are unreliable and at times unavailable. To address this, the system supports disconnected work, and stores data locally. When network connections become available, the client application forwards transactions to the server, and the server sends cached transactions to the client. All transactions are stored in FIFO queues, so transactions are always sent in the order that they occurred. The Mohoc client was initially developed to operate on laptop computers with wireless modems. Later, Pocket Mohoc, a Pocket PC version of the client, was developed to support home health aide workflows since they require only a subset of the functionality that is needed by professional workers.

Mohoc has three main user-interface screens, and each screen supports a distinct step in the daily activities of home care workers. The *schedule view* allows the worker to view their weekly schedule and allows them to plan and set their weekly appointments. The *daily agenda view* allows the worker to access an interactive daily agenda that can be revised as the workday unfolds. The *chart view* allows workers to access an interactive chart for each of their patients, and it provides electronic versions of their forms so that they can fill out their daily paperwork for the selected patient. Collaboration support is provided as an adjunct to these autonomous work activities. This is done using tools for explicit communication which include a group discussion tool and sticky notes that can be placed on the shared workspace or in documents. The system also provides several types of awareness information to help workers to coordinate their work activities without expending significant effort including: viewing histories and modification histories for

shared artifacts (e.g. clinical documents or communications), awareness flags that indicate when new artifacts are added or when existing artifacts are modified, and awareness representations that are displayed in tools that support individual work.

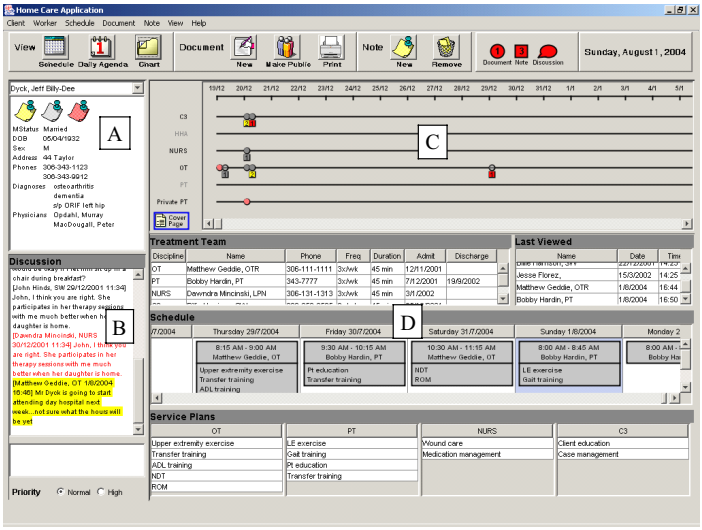

Figure 1. Chart view with cover page selected. A: Client summary region. B: Discussion tool. C: Document overview region. D: Document viewing region.

Figure 1 shows a screenshot of the chart view and illustrates several of the design approaches. The screen is primarily used for maintaining clinical documents such as assessments, progress notes, and discharge summaries. The documents are merged into a shared document repository so that they are accessible by all team members. A timeline-based overview of this space is shown in C, and area D displays the content of the selected document. The overview area (C) also shows the private document space that is available to the physiotherapist worker who is logged into the system. A line at the bottom of the overview region is labeled “Private PT”, and it contains documents that were created by the user and that are not viewable by others. In Figure 1, area D shows the chart view “cover page”, a summary page that displays information about other workers that treat the selected patient. For example, an area labeled “Last viewed” shows the times and dates when other workers accessed the selected patient’s chart. The area labeled “Schedule” shows the patient’s schedule, the times the patient will be visited by other workers, and the treatments the workers will provide. Communication tools are also shown. Sticky notes are attached to the patient’s chart and are shown in A, and a group discussion tool is shown in B. These are both attached to the workspaces used to carry out autonomous work activities, but can be selectively ignored by workers.

Field Trials

We carried out two field trials where the Mohoc system was used by home care teams to support team members’ daily activities. The field trials allowed the groupware system and the underlying design framework to be evaluated. During the trials, participants used the client application to support the care of patients who consented to participate in the trials.

Prior to each trial, each worker participated in two training sessions. Each session lasted between 45 minutes and 1 ½ hours, and duration varied with the technical expertise of the trainee. First, each participant was trained on the care and maintenance of the client device (laptop or handheld) and modem, and on the operating system installed on the device. Each worker also received preliminary training on the client application. Workers were given the client device and were encouraged to use them so that they could become more familiar with the technology. A second training session was scheduled with each worker 2 weeks after the first session. During the second training session, workers were given in-depth training on the client application, and on field trial logistics.

The first trial lasted 2 ½ months. During that time, Mohoc was used by a treatment team of six home care workers from five different disciplines, and the team used the application to support the treatments that they provided to a single shared patient. The second field trial was larger in scope—it lasted 3 months and included 3 patients and 10 participants, and it included the Mohoc and Pocket Mohoc applications. The underlying intent of the second trial was to expand on the investigation started in the first, but with patients with conditions varying in acuity. This variation, it was hoped, would provide an opportunity to examine different levels of interdependence within treatment teams so that a range of work patterns could be considered.

During each field trial, two types of data collection procedures were used. First, two rounds of interviews were conducted with each participant. The first round was conducted midway through the trial, and the second was conducted at the end of the trial. All interviews were audio recorded for later analysis. The interviews were semi-structured and focused on gathering information about how features were utilized by participants and about participants' opinions of features. They also provided an initial look at how the system impacted work practice. Second, participants' interactions with the system were recorded using system logs. System logs contained timestamps and information about the specific interactions that workers carried out with the application.

During the trials, participation varied with each participant's level of involvement in patient care. Over the course of 162 days, there were a total of 240 unique sessions where a participant logged into the system and generated at least one network transaction. There were a total of 5153 transactions during the trials. A transaction was an action taken by a user that generated a network message that was sent to the server. On average, participants carried out 21.47 transactions per session. At times, some participants accessed the system sporadically, but the field trial duration enabled enough data to be collected from each user so that a reasonable evaluation could be carried out. Additionally, a range of system features were used by the participants over the course of the trial, and this generated enough data to allow most of the major features (and the underlying design approaches) to be evaluated.

Results

Each design approach was instantiated in features found in the Mohoc system, and this mapping was used to evaluate the design approaches (see Table V). Each approach was evaluated by analyzing field trial data to determine how successful the corresponding system features were at

supporting work and collaboration in home care teams. Interview data and system logs were analyzed to determine:

- patterns of system use,
- participants' opinions of the features,
- the impact that the system had on work practice (based on participant report).

Most of the features that implement the design approaches were well received during the field trials. Table V summarizes the field trial results. Each design approach is listed along with the Mohoc features that instantiate the approach. The result summary column provides a brief description of the evaluation result for each approach. The evaluation results are positive in most instances and indicate that most of the features were successfully integrated into existing work practices in home care, and that support for low cost collaboration features was beneficial to workers during the trials. Overall, this suggests that most of the design approaches are useful at adding consideration for loosely coupled work practice to groupware design in a way that allows the system to be successfully incorporated into existing work practices.

Table V. Summary of field trial results

Design approach	Mohoc features	Result summary
Support autonomy and flexibility	Supports current autonomous workflow, does not force explicit collaboration	System used primarily to support autonomous activities: documentation, scheduling
Consolidate information buffers	Stores clinical documents in a shared document repository	Participants regularly viewed others' clinical documents and had a positive view of this feature
Support individual workspaces and discretionary sharing	Allows documents to be maintained in unshared personal workspaces	Individual space used to leave notes to self, for experimentation, and to temporarily store documents until completion
Integrate collaboration with features for individual work	Provides collaboration tools that are associated with individual workspaces; Embeds collaborative information in tools for individual work	Collaboration features used less frequently than individual work features; used to augment workers' current work activities
Facilitate asynchronous awareness	Tracks viewing and modification histories for artifacts; flags new / newly modified content	Participants reported using flags to track relevant content; modification histories to manage shared editing of documents
Support loose coordination	Embeds information about others' treatment times and treatment activities in scheduling tools to facilitate adjustment without negotiation	Several participants reported using information in the system to tailor treatment activities and times
Support loose communication	Provides asynchronous communication tools: sticky notes, group discussion tool	Used to communicate primarily urgent information (falls, hospitalizations). Participants report more communication than in unsupported work.
Support shifts to tighter coupling	Provides limited information about others' availabilities to facilitate face-to-face and phone conversation	Participants found information useful; would have liked more detail to facilitate phone conversations while in office
Preserve flexible group organization	Provides information about others' treatment frequencies	Participants did not report making use of this feature

The features that support autonomous work activities were used most frequently. Workers primarily used the system to maintain clinical documents, to manage their schedules, and to update patients' treatment plans. Many participants also utilized their personal, unshared workspace regularly. They often left incomplete documents in their personal space, and once they were completed, they moved them to the shared workspace so that they were viewable by others. Others maintained personal notes and reminders using sticky notes even though the feature was initially intended for use as an interpersonal communication tool. This is illustrated by the following example:

> Interviewer: "You left sticky notes for yourself? How did you use them?"
>
> Nurse: "I put things in there to remind myself to pass on messages to other people. Like, for example, an LPN. Or I left a message to myself to pick up a particular type of supply. Something that I may would have written in my own calendar book or something, or put a nurse to nurse memo on the front of our file, so instead of…put it on there as a reminder to me to do something in particular, so I used it that way."

During interviews, several participants reported modifying their treatments and schedules based on information that was provided through Mohoc's coordination features. In a discussion about the schedule tools and the shared document repository, a participant offered an example of how she tracked another worker's treatment activities since they had direct relevance to her own treatments:

> Participant: Last week <patient name>'s chest was bad so <worker's name> was in there every day, and I mean, I could pick up on that, that I wouldn't normally pick up on. So that is probably the biggest advantage, that you can see what the other people are doing and that they've…noticed any changes in <him/her> or whatever.

Features that support explicit communication were used more intermittently than autonomous work features. However, the frequency of communication that did take place was greater than what was seen during observations of unsupported work. Most of the communication that took place was not routine in nature, but instead was used to inform the team of unusual occurrences or observations such as patient hospitalizations or health emergencies. For example, during the second field trial, a patient was hospitalized and a participant posted a brief public message using the discussion tool: "daughter came called EMS went to hospital." During an interview, a participant describes the value of the communication support in allowing more direct communication, but suggests that the true value is to pass on "a little message" rather than to sustain regular communication:

> Interviewer: How did the communication support, like the discussion and the sticky notes, impact your work?
>
> Participant: Yeah, that's not something we had the sort of ability to do anyway before. You know, a message or something. And we really need it. Because there's no connection. Even with the home health aides, they're never in the office at the same time that we are, so there is never an opportunity to pass on a little message. It's always got to be second hand through the supervisor to them kind of thing, so it's always a three way system. So this let me talk to them without going through the supervisor first.

Some of the design approaches could not be fully evaluated due to oversights in the implementation or due to limited utilization of features by participants. In the next paragraphs, we

discuss two approaches that were difficult to evaluate: supporting shifts to tighter coupling and supporting flexible group organization.

Support shifts to tighter coupling. The field trial results suggest that supporting shifts to tighter coupling may be valuable, but the Mohoc system missed opportunities for supporting this approach fully, and as a result, it was not evaluated as extensively as it could have been. The Mohoc system did not record information about workers' office hours, which would have helped facilitate meetings and phone conversations in the office. Participants recommended the addition of this information in exit interviews during the trials. While this approach does not need to be revised given the evidence available from the trial, it would benefit from further evaluation in other settings.

Support flexible group organization. The Mohoc system did not provide different participation modes, making it difficult to fully evaluate this approach. For example, the system did not allow workers to indicate to others that they are less involved with a patient so that more involved members can notify them when increased involvement is needed. Since support for this approach was only minimally provided, it was not possible to fully evaluate its usefulness.

Discussion

Loose coupling is common in many work domains including education, health care, and knowledge work, but it has not previously been studied in detail in CSCW. In this research, we attempted to address the need for a more informed approach to designing groupware systems for loosely coupled workgroups by developing a design framework based on literature in organizational research fields, and on findings from home care treatment teams. The framework provides a contextual model that characterizes loose coupling in the workplace, and a set of design approaches for tailoring systems to the work practices in loosely coupled settings.

Our evaluation findings from home care are generally positive and suggest that the framework was useful in specializing the groupware design process for loose coupling. However, since the framework was only evaluated in a single setting, further research is needed to determine how well it will generalize to other loosely coupled groups. Furthermore, the framework was developed concurrently with home care data collection activities, so it is a possible that the framework may be tailored to the home care setting rather than to loosely coupled groups in general, and that evaluation results may also reflect this bias.

One of the difficulties we encountered in evaluating the design framework is that the theoretical components are difficult to test in a rigorous fashion since there are limited controls in a field study. Furthermore, since the ultimate test of a design framework is in how well it contributes to the development of systems that are well suited to the needs of the users, the theoretical propositions cannot be tested directly. Instead, the system itself must act as a surrogate for the framework during an evaluation. This makes it difficult to evaluate a framework with a high level of rigor, since, for example, it is difficult to measure how well features instantiate a framework and to what degree. It is also difficult to attribute success of failure of an implementation to the framework in entirety, since design is an imprecise activity, and since success or failure may be due to factors that fall outside of the framework's focus. We

acknowledge that this is a preliminary step in understanding design for loosely coupled workgroups and that significant further work needs to be carried out. In part, we hoped to overcome some of these limitations by basing many of our theoretical assumptions on literature on loose coupling in organizational research fields. However, the design approaches extend beyond organizational research, and it is here that further validation is needed the most.

References

Aldrich, H. (1979): *Organizations and Environments*, Prentice Hall, Englewood Cliffs, NJ.

Bellotti, V., Bly, S. (1996): 'Walking away from the desktop computer: distributed collaboration and mobility in a product design team', *Proc. CSCW'96*, ACM Press, pp. 209-218.

Bertrand, A.L. (1972): *Social Organization: A General Systems and Role Theory Perspective*, F.A. Davis, Philadelphia.

Brusoni, S., Prencipe, A. (2001): 'Managing knowledge in loosely coupled networks: exploring the links between product and knowledge dynamics', *Journal of Management Studies*, 38(7), pp. 1019-1035.

Churchill, E.F. and Wakeford, N. (2001): 'Framing mobile collaboration and mobile technologies', in Brown, B., Green, N., Harper, R. (eds.): *Wireless World: Social and Interactional Implications of Wireless Technology*, New York, Springer-Verlag.

Daft, R.L., Lengel, R.H. (1986): 'Organizational information requirements, media richness and structural design', *Management Science*, 32(5), pp. 554-571.

DiTomaso, N. (2001): 'The loose coupling of jobs: the subcontracting of everyone?', in Berg, I. and Kalleberg, A.L. (eds.): *Sourcebook of labor markets: evolving structures and processes*., Kluwer Academic/Plenum, New York, pp 247-270.

Fagrell, H., Forsberg, K., Sanneblad, J. (2000): 'FieldWise: a mobile knowledge management architecture', *Proceedings CSCW 2000*, ACM Press, pp. 211-220.

Firestone, W. (1985): 'The study of loose coupling: problems, progress and prospects', in Kerckhoff, A. (ed.): *Research in Sociology of Education and Socialization*, Greenwich, CT, JAI Press, 5:3-20.

Foster, W. (1983): *Loose-coupling Revisited: A Critical View of Weick's Contribution to Educational Administration*, Victoria University Press, Victoria, Australia.

Grinter, R.E., Herbsleb, J.D., Perry, D.E. (1999): 'The geography of coordination: dealing with distance in R&D work', *Proc. GROUP 1999*, ACM Press, pp. 306-315.

Hasenfeld, Y. (1983): *Human Service Organizations*, Prentice Hall, Englewood Cliffs, NJ.

Horne, S. (1992): 'Organization and change within educational systems: some implications of a loose-coupled model', *Educational Management and Administration*, 20(2), pp 88-98.

Kmetz, J.L. (1984): 'An information-processing study of a complex workflow in aircraft electronics repair', *Administrative Science Quarterly*, 29(2), pp. 255-280.

Kouzes, J.M. and Mico, P.R. (1979): 'Domain theory: an introduction to organizational behaviour in human service organisations', *Journal of Applied Behavioural Sciences*, 15(4), pp. 449-469.

Lei, D., Hitt, M.A., Goldhar, J.D. (1996): 'Advanced manufacturing technology: organizational design and strategic flexibility', *Organization Studies*, 17(3), pp.501-523.

Litterer, J.A. (1965): *The Analysis of Organizations*, John Wiley & Sons, New York.

Lorsch, J.W. (1973): 'An open-system theory model for organizational research', in Negandhi, A.R. (ed.): *Modern Organizational Theory: Contextual, Environmental, and Socio-cultural Variables*, Kent State University Press, Kent, Ohio, pp. 132-144.

Lutz, F.W. (1982): 'Tightening up loose coupling in organizations of higher education', *Administrative Science Quarterly*, 27, pp. 653-669.

Monane, J.H. (1967): *A Sociology of Human Systems*, Meredith Publishing, New York.

Olson, J.S. and Teasley, S. (1996): 'Groupware in the wild: lessons learned from a year of virtual collocation', *Proc. CSCW 1996*, ACM Press, pp. 419-427.

Orton, J.D. and Weick, K.E. (1990): 'Loosely coupled systems: a reconceptualization', *Academy of Management Review*, 15(2), pp. 203-223.

Perrow, C. (1999): *Normal Accidents: Living with High-risk Technologies*, Princeton University Press, Princeton, NJ.

Pinelle, D. (2004): *Improving Groupware Design for Loosely Coupled Groups*, Ph.D. thesis, Department of Computer Science, University of Saskatchewan, Canada.

Pinelle, D. and Gutwin, C. (2003): 'Designing for loose coupling in mobile groups', *Proceedings of GROUP 2003*, ACM Press, pp. 75-84.

Rubin, I.S. (1979): 'Retrenchment, loose structure and adaptability in the university', *Sociology of Education*, 52(4), pp. 211-222.

Scheid-Cook, T.L. (1990): 'Ritual conformity and organizational control: loose coupling or professionalization?', *The Journal of Applied Behavioral Science*, 26(2), pp. 183-99.

Scott, W.R. (1987): *Organizations: Rational, Natural, and Open Systems*, 2nd ed., Prentice-Hall, Englewood Cliffs, NJ.

Scott, W.R. (1985): 'Systems within systems: the mental health sector', *American Behavioral Scientist*, 28(5), pp. 601-618.

Smith, P.B. (1973): *Groups Within Organizations: Applications of Social Psychology to Organizational Behaviour*, Harper & Rowe, London.

Staber, U., Sydow, J. (2002): 'Organizational adaptive capacity - a structuration perspective', *Journal of Management Inquiry*, 11(4), pp. 408-424.

Tyler, W. (1987): 'Loosely coupled schools: a structuralist critique', *British Journal of Sociology of Education*, 8(3).

Weick, K.E. (1982): 'Management of organizational change among loosely coupled elements', in Goodman, P.S. (ed.): *Change in Organizations: New Perspectives on Theory, Research, and Practice*, Jossey-Bass, San Francisco.

Weick, K.E. (1980): 'Loosely coupled systems: relaxed meanings and thick interpretations', Paper presented at the Annual Meeting of the American Educational Research Association, Boston, 1980.

Weick, K.E. (1976): 'Educational organizations as loosely-coupled systems', *Administrative Science Quarterly*, 21, pp. 1-21.