Designing CSCW Applications to Support Loose Coupling in Organizations and Groups

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Abstract. In loosely coupled groups and organizations, work units are autonomous, share few or weak interdependencies, and collaborate infrequently. The complex social aspects of loosely coupled work have significant implications for the design of CSCW technologies. However, it is unclear how CSCW systems should be designed to support loosely coupled groups and organizations. Theories and design frameworks have not yet been developed to guide design, and current CSCW research on loose coupling is limited and often overlooks important underlying organizational, social, and environmental issues. In this paper, I will take a first step in developing an understanding of CSCW design for loose coupling by surveying organizational research literature to identify the social and organizational aspects of loose coupling that are relevant to the design of CSCW systems. Then, I will survey CSCW literature to identify design approaches that are currently used to support loose coupling. I will close by synthesizing the findings from both areas and will discuss what organizational research findings suggest about future CSCW designs.

Keywords: loose coupling, computer-supported cooperative work, CSCW design.

1. INTRODUCTION

Designing applications for groups and organizations is significantly more difficult than designing for single users. Computer-supported cooperative work (CSCW) designers must consider complex social and organizational issues in addition to issues that are traditionally considered "single user" such as visual perception and human factors. The need to account for multi-person complexities has lead to the adoption of sociology theories and methods by the CSCW community (Hughes et al. 1994; Halverson 2002), and approaches such as ethnography and activity theory are accepted means for investigating social aspects of work to inform the design process (Halverson 2002).

One important social characteristic of work that has received attention in CSCW literature is the level of coupling between workers in real-world work settings. Salvador et al. (1996) describe coupling as the extent to which people work together. Since workers adopt different patterns of work and collaboration based on their level of coupling with others, coupling patterns have implications for the design of CSCW systems.

In CSCW literature, two types of coupling have been described: tight and loose. According to Olson and Teasley (1996, p.422), "tightly coupled work involves two or more people whose work is directly dependent on each other, and their work typically involves a number of interactions to complete the task. Immediate interaction helps them to communicate clearly or to negotiate some resolution…At the other extreme, loosely

coupled work is work in which people need to be aware of others' activity and decisions, but without the need for immediate clarification or negotiation."

In this paper, I will focus on loose coupling, and the role CSCW technologies can play in supporting loosely coupled workers. In CSCW literature, researchers and developers have considered how CSCW applications should be designed for loosely coupled work. However, the level of analysis used in CSCW research overlooks many of the social subtleties of loose coupling that have been identified in other areas of organizational research. CSCW literature does not consider the organizational and environmental factors that can shape the adoption of loosely coupled work patterns, and does not consider the tradeoffs inherent in introducing collaborative tools to loosely coupled workers.

Given the current level of analysis in CSCW research, it is unclear how CSCW applications should be designed to address the complexities of loose coupling in groups and organizations. Currently, formal design frameworks have not been developed, and it is not clear how CSCW design decisions should be aligned with loosely coupled work patterns. In this paper, I will take a first step in developing an understanding of design for loosely coupled groups and organizations by surveying literature that covers the social and technical aspects of design.

In the first half of this paper, I will survey organizational research from a number of fields including organization theory, sociology, education, management, administration, and systems theory. Organizational research provides insights into social and organizational aspects of loosely coupled work that are overlooked in CSCW, but that are still important to system design. I will discuss a number of these contributions, including: definitions of loose coupling; open systems theory and loose coupling; relationships and interactions between loosely coupled elements; organizational and environmental causes of loose coupling; and the effects of loose coupling.

In the second half of this paper, I will survey CSCW literature on design for loosely coupled collaborators. CSCW literature focuses on the communication and coordination practices that connect workers, and how technologies can improve those processes. I will discuss work on loose coupling in CSCW, including CSCW definitions of loose coupling and factors related to the adoption of loose coupling in organizations and groups. I will also discuss the CSCW design approaches that are used to support loosely coupled workers, including: real-time designs that tighten coupling, real-time designs that use mixed WYSIWIS to support mixed coupling, and asynchronous designs that accommodate schedule variability and/or mobility.

The major conclusion of this paper is that future practical and theoretical design work on loose coupling needs to combine both top-down and bottom-up views of work. Rather than only focusing on collaboration between members of workgroups, and on collaborative barriers that might exist between members, attention also needs to be given to influences that may be external to the workgroup. For example, organizational and environmental pressures can lead to the adoption of loosely coupled work patterns, but these causes can be overlooked by focusing exclusively on a limited subset of the larger organization. These causes are relevant to CSCW design, since design decisions can impact these underlying factors.

2. THE SOCIAL-TECHNICAL DIMENSION OF DESIGN

When designing CSCW systems, developers must attempt to achieve some level of congruence between the technical implementation and users' social and organizational contexts. O'day et al. (1996; 1998) describe this as the "social-technical" dimension of design, and state that in CSCW, there are (1998, p. 316) "social implications of technical design choices and technical implications of social design choices." Grudin (1994) points out the importance of aligning the social and the technical (p.97): "Groupware may be resisted if it interferes with the subtle and complex social dynamics that are common to groups."

Most formal CSCW design approaches are intended to help developers tailor technical designs to target users and their social and organizational work contexts. Three types of design methods are discussed in CSCW literature. First, techniques that are used for single user development but that are strongly based on field observations and/or users' involvements are often used in the design of CSCW systems (Halverson 2002). These include contextual inquiry and contextual design (Beyer and Holtzblatt 1998; Holtzblatt and Beyer 1993); participatory design (Greenbaum and Kyng 1991; Muller 1991); and user centered design (Norman and Draper 1986). Second, several design approaches are specific to CSCW and attempt to bridge information about tasks and collaboration practices into the design process. However, these are not strongly oriented around specific social science theories. These include: the mechanics of collaboration (Gutwin and Greenberg 2000); groupware walkthrough (Pinelle and Gutwin 2002; Pinelle and Gutwin 2001); groupware task analysis (van der Veer and van Welie 2002; van der Veer et al. 1996); collaborative usability analysis (Pinelle et al. 2003); and heuristic evaluation for groupware (Baker et al. 2002). Third, social science theories and approaches are used to carry out and analyze the results of field observations, and to

guide design. These include: ethnography (Shapiro 1994; Blythin et al. 1997; Hughes et al. 1994), activity theory (Collins et al. 2002; Miettinen and Hasu 2002; Fjeld et al. 2002), distributed cognition theory (Ackerman and Halverson 1998; Halverson 2002), and grounded theory (Grinter 1999; Grinter 1998; Fitzpatrick et al. 1996).

In addition to formal design approaches, CSCW literature also includes design recommendations and frameworks that provide guidance in designing for groups and organizations that operate in specific domains or that have specific characteristics. These recommendations are commonly based on the observations, experiences, and insights of developers and researchers working in the field. For example, Heath and Luff (1998) discuss design for mobile workers; Scott et al. (2003) discuss design for co-located workers using tabletop displays; and Brown and Chalmers (2003) discuss design for tourists.

Even though CSCW researchers have presented recommendations and frameworks for a range of domains and group types, it is still not clear how social and technical aspects of design should be aligned for loosely coupled groups and organizations. In the rest of this paper, I will take a first step in exploring CSCW design for loose coupling. I will begin by considering the social and organizational dimension of design by surveying organizational research on loose coupling.

3. LOOSE COUPLING IN ORGANIZATIONAL RESEARCH

Organizational research provides a more nuanced view of the social and organizational aspects of loose coupling than is generally seen in CSCW literature. These studies provide details that are often missing in CSCW such as the environmental and organizational causes of loose coupling; the organizational effects of loosely coupled work patterns; and the patterns of work and collaboration that are seen in loose coupling. Most of the relevant literature in organizational research presents studies of real-world work, or presents conceptual work based on real-world observations. Therefore, organizational research has relevance to the design of CSCW systems, since it describes social and organizational aspects of work, albeit with a different frame of reference than is seen in CSCW.

The theories and findings reported in organizational research have the potential to contribute to the design of CSCW systems in at least three major ways. First, developing a detailed understanding of loose coupling in work settings can sensitize designers to important features of loose coupling when they observe real-world work settings. Second, organizational research can provide a core set of concepts and a common vocabulary for

describing specific work characteristics and how they can be addressed with technical design approaches. Third, concepts from organizational research can help contribute to the development of design frameworks and theories for designing for loose coupling.

In the next sections, I will survey loose coupling literature in organizational research. This literature comes from a number of fields: organization theory, sociology, education, management, administration, and systems theory. I will base the discussion around major themes found in literature on loose coupling, but I will organize the discussion so that it introduces basic theoretical building blocks, and then progresses to more complex organizational issues. In these sections, I will discuss the following high-level themes:

- Definitions of loose coupling in organizational research
- Open systems theory
- Relationships and interactions between elements
- Causes of loose coupling
- Effects of loose coupling

3.1 Definitions of loose coupling in organizational research

The term "loose coupling" seems to have been first used by Glassman (1973), who used it to describe linkages between elements in living systems including cell and organ, organism and group, organization and society. According to Glassman, systems are loosely coupled if they have few variables in common or if the variables they have in common are weak relative to other factors that influence them. When systems are loosely coupled, they can operate relatively independently of each other. However, in the case where systems share a large number of common variables or where those variables are strong, interdependencies increase between the systems, and their independence from each other decreases.

In an influential paper, Weick (1976) adopts the notion of loose coupling to describe organizational structures in education. Wieck describes how operational elements in schools, such as teachers, are often loosely coupled with each other, with managers (e.g. principals), and with district administrators. Because of the weakness of these links, teachers have autonomy and flexibility in carrying out their daily work, and principals and administrators have difficulty in instituting change within schools. Weick (p. 3) defines loose coupling, and elaborates on some of its complexities:

> "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."

In a later paper, Orton and Weick (1990) revisit Weick's early work (1976), and attempt to formulate a more precise definition for 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 (p. 205), "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." They argue that the unidimensional interpretation overlooks many of the intended subtleties in Weick's earlier work, and that it does not emphasize the connectedness that is a necessary part of loose coupling.

Instead, Orton and Weick advocate using what they describe as 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 respond to the actions of other elements in the system (p.205):

> "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."

Orton and Weick's definition is perhaps more clearly articulated by Foster (1983). According to Foster (p. 11), "loose coupling implies the tying together of subsystems in such a fashion that neither can do without the other but neither has much control over the other."

Ingersoll (1993, p. 89) summarizes many of the characteristics of loose coupling that are implicit in the definitions that are given by other authors:

1. unclear, diverse or ambiguous organizational means and goals;
2. low levels of coordination of employees' productive activities;
3. low levels of organizational control:
   high levels of employee autonomy
   low levels of managerial authority

3.2 Open systems theory

While loose coupling literature often focuses on describing relationships between large organizational subunits, the theoretical base (e.g. Weick 1976; Glassman 1973; Orton and

Weick 1990; Foster 1983) is built on an open systems model. Systems theory is based around the notion of a system, which Scott (1987) describes as (p. 76), "an assemblage or combination of parts whose relations make them interdependent." The generality of the system definition allows significant room for variability between systems. For example, the relationships between system elements can be weak or strong, stable or unstable, reactive or not, and system elements can vary in size and complexity (Scott 1987).

This systems foundation provides flexibility to loose coupling theory, since systems theory does not place constraints on the size or composition of system elements. This flexibility is seen in the application of loose coupling theory. For example, loose coupling theory is frequently used to describe relationships between individuals (Orton and Weick 1990; DiTomaso 2001), between organizational subunits (Meyer and Rowan 1977; Weick 1976), and between organizations (Brusoni et al. 2001). In a survey of loose coupling literature, Orton and Weick (1990) describe eight types of elements that have been studied in loosely coupled systems: individuals, subunits, organizations, hierarchical levels, organizations and environments, activities, ideas, and intentions and actions.

Loose coupling research is based on an open systems model (Scott 1985; Scott 1987; Lei et al. 1996) since the study of social systems must account for both internal and external influences on system elements. Open systems theory differs from closed systems theory (which is often used to describe mechanical systems) since it is based on the notion that systems dynamically interact with their external environments (Boulding 1956; Katz and Kahn 1978; Thompson 1967). This interaction allows systems to act to prevent deterioration and disruption, and to restore equilibrium. Scott (1985, p. 601) points out that open systems "are capable of adaptive upgrading, becoming more differentiated and elaborate in their structures and processes over time."

Katz and Kahn (1978, p. 122) define the environment as "everything in the universe, except the organization under study." However, they qualify this by stating that it is more productive to focus on those aspects of the environment that interact directly with organizations. They identify five environmental sectors that strongly influence organizations (p. 124): the cultural environment, the political environment, the economic environment, the technological environment, and the ecological environment.

The characteristics of an organization's environment place pressures on the organization, and to be successful, the organization must adopt behaviors and structures that allow it to handle those demands (Georgopoulos 1973, p. 102). Lorsch (1973, p. 132) argues that "there must be a fit between internal organizational characteristics and

external environmental requirements if an organization is to perform effectively in dealing with its environment."

Since organizations respond to their environment, specific environmental characteristics can lead to the adoption of structural and behavioral patterns in organizations. For example, unpredictable and changing work environments have often been described as one of the primary causes of loose coupling between an organization's elements (Orton and Weick 1990; Meyer and Rowan 1977; Lei et al. 1996). Lorsch (1973) illustrates this point (pp. 135-136):

> "We would predict that in effective units involved in more uncertain parts of the environment, members would perceive less structure, would feel that they have high influence over their own work and would perceive egalitarian influence distribution in general, and that supervisory styles would be seen as participative. The opposite set of conditions would fit a unit effectively dealing with a more certain environment."

3.3 Relationships and interactions between elements

Loose coupling describes the strength of connections between well-defined and autonomous system elements. Loose coupling implies that system elements "respond to each other in a circumscribed, infrequent, slow, or unimportant manner" (Hasenfeld 1983, p. 150). In organizations, Hasenfeld (1983) states that loose coupling results in weakly connected and weakly coordinated tasks and activities, and in a weak system of administrative control over activities. Staber and Sydow (2002, p. 417) point out that in loosely coupled organizations, "control is decentralized and information travels slowly and unevenly."

Beekun and Glick (2001; 2001) attempt to characterize the interactions between coupling elements in more concrete terms. According to them, organizational elements can be coupled by work related communication; informal, social communication; mutual participation in work tasks; and resource exchange. The quality of coupling relationships can be described by the level of interdependence between elements and by the strength, directness, and consistency of interactions.

In the rest of this section, I will further consider the relationships and interaction mechanisms that are seen in loose coupling. I will focus on the interdependencies that characterize "coupling" between system elements. First, I will discuss the relationship between interdependence and coordination in organizations, and then I will briefly consider the role that communication plays in managing interdependence.

3.3.1 Interdependence and coordination

Interdependence is an important concept in loose coupling theory and in systems theory since it 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). In loose coupling theory, these interdependencies are weak, since system elements that are loosely coupled share few or weak "variables" (Glassman 1973; Weick 1976).

The interdependencies seen between elements play a key role in shaping the work processes that are seen in organizations. This can be seen in the work of Thompson (1967), who identifies three types of interdependence: pooled interdependence, sequential interdependence, and reciprocal interdependence (see Table 1). For each successive type of interdependence in Thompson's typology, coordination becomes more difficult and costly. As is shown in Table 1, pooled interdependence can be managed with work standardization, which allows the organization to coordinate work with minimal effort. Sequential interdependence often requires planning and scheduling, and does not place a significant burden on the organization unless unexpected events lead to revisions in the sequence of work activities. Finally, when reciprocal interdependence exists, mutual adjustment is often needed, which requires significant effort since elements must monitor each other and must regularly communicate about work activities.

Table 1. Thompson's (1967) interdependence typology and coordination mechanisms

Interdependence type	**Coordination type**
Pooled interdependence. The work is interdependent since the efforts of each element contribute to an overall shared goal.	*Standardization.* The development of rules and routine to guide work practices.
Sequential interdependence. Some activities must be carried out before those of others, and one element must act before another element can.	*Planning and scheduling.* Timing and order of work are specified.
Reciprocal interdependence. The interdependence is symmetrical; elements mutually influence each other, and the output of one element is the required input of another element.	*Mutual adjustment.* Elements must monitor and respond to other elements' activities through ongoing communicate.

March and Simon (1993, pp. 180-182) consider the effort that is required to coordinate work, but they focus on the relationship between coordination mechanisms

and the predictability of work situations (as I will discuss in section 3.4.3, loose coupling is usually associated with unpredictable work situations, e.g. Orton and Weick 1990; Meyer and Rowan 1977; Lei et al. 1996). They argue that when work situations are predictable and repetitive, organizational subunits can structure themselves so that they can account for interdependencies with other subunits. This predictability gives subunits a high tolerance for interdependence, since the subunit is organized to accommodate expected work patterns. However, as variability and unpredictability increase in the work situation, the burden of coordinating work and managing interdependencies increases as well.

March and Simon (1993, pp. 181-182) offer a typology for coordination that is similar to Thompson's. They state that interdependencies in standardized, predictable work situations can be managed by *coordination by plan*, where schedules and plans are established in advance. However, when the work situation is variable and unpredictable, *coordination by feedback* is usually required, where new information is transferred between organizational subunits.

3.3.2 Interdependence and communication

Communication plays an important role in managing interdependence between elements in organizations. Simon (1997, p. 208) defines communication as "any process whereby decisional premises are transmitted from one member of an organization to another." He describes two types of communication in organizations (p. 211): formal and informal. Formal communication consists of media and communication channels that are deliberately established, and informal communication is based on social relationships. Common channels for formal communication are oral communication, memoranda and letters, paper-flow, records and reports, and manuals. Informal communication often takes the form of "shop talk" and allows workers to exchange information and advice.

March and Simon (1993) argue that an organization's ability to handle a high level of interdependence is tied to its ability to manage communication. They state that (pp. 183-184), "the greater the efficiency of communication within the organization, the greater the tolerance for interdependence." They also hypothesize that (p. 189) "the greater the communication efficiency of the channel, the greater the communication channel usage."

3.4 Causes of loose coupling

Work in organizational research has identified a number of environmental and organizational characteristics that help explain why systems adopt loosely coupled organizational patterns. While it is not possible in a strict sense to say that specific

conditions cause loose coupling, some characteristics seem to make the adoption of loose coupling more likely.

In this section, I will present an overview of the conditions that facilitate loose coupling. While the conditions discussed here are identified as potential causes of loose coupling, it has also been pointed out that some conditions may be the result of loose coupling (e.g. Foster 1983, p. 13). However, I will base the discussion around the stated intent of the authors who identify these relationships. It should also be pointed out that the conditions presented here are not always mutually exclusive, and some conditions are often seen in combination with others. I will discuss six conditions:

- *Prior socialization*. Organization members have common training, socialization, and/or work experiences.
- *Cryptic surveillance*. Inspection of organization members' activities is weak and undemanding.
- *Environmental uncertainty, complexity*. The organization operates in an uncertain and/or complex environment.
- *Incompatible external expectations*. Environmental expectations for organizational behavior are incompatible with operational demands.
- *Professionalism*. The organization has professional employees.
- *Specialized knowledge, expertise*. Employees have specialized knowledge and/or expertise.

3.4.1 Prior socialization

Foster (1983) reports on a paper by Weick (1980) who claims that one of the potential causes of loose coupling in organizations is prior common socialization of organization members. Members of organizations may have common training, socialization, and work experiences "which influence their perceptions about the goals…and about the means through which these goals ought to be attained" (Hansenfeld 1983, p. 156). These shared perceptions provide workers with an understanding of the actions that others who have similar training and socialization are likely to take, and of the rules associated with fulfilling specific roles within the organization. This knowledge frees workers from the need for ongoing coordination with others who are similarly socialized, since they are able to anticipate others' actions.

Weick's claim is supported by the work of Gamoran et al. (2000) who suggest that common socialization allows workers to operate on *unexamined assumptions* about the actions of others. They illustrate this by providing an example from an educational setting

(pp. 43-44), "…fourth grade teachers may assume that third-grade teachers are introducing concepts on which they will build when they teach the same students in the following year. Similarly, teachers teaching the same subject area in different grades share a common disciplinary socialization that yields a coherent approach to teaching despite the absence of formal mechanisms of coordination."

3.4.2 Cryptic surveillance

Another condition that can facilitate loose coupling is limited monitoring and awareness of others' activities. Weick (1980) calls this *cryptic surveillance* and states that, "this occurs when the inspection of members' activities, of funds spend, or of programs implemented, is weak and undemanding." Cryptic surveillance can occur between administrators and subordinates, or can occur laterally between peers (e.g. Scheid-Cook 1990, pp.191-192).

Cryptic surveillance is frequently seen in conjunction with other conditions that facilitate loose coupling such as prior socialization (e.g. Gamoran et al. 2000) or incompatible external expectations (e.g. Meyer and Rowan 1977). However, it can also stand alone as a cause of loose coupling, as Hasenfeld (1983, pp. 156 – 157) shows when discussing administrators' abilities to monitor the services that staff members provide to clients in human service organizations (e.g. health care, education):

> "With few exceptions, their content is not readily open to inspection for several reasons: (1) numerous legal and ethical restrictions protect the confidentiality of the information exchanged between client and worker; (2) human service practitioners strongly believe that the quality of the relationship and the trust between them and the client will be adversely affected by any external intrusion; (3) the lack of reliable and valid performance evaluation criteria makes the direct observation of staff-client relations a highly volatile supervisory tool that may cause serious conflicts over interpretations of observations; (4) administrative costs of direct monitoring of staff-client relations are exceedingly high because the organization cannot fully anticipate or control their initiation and because direct monitoring requires a substantial commitment of personnel and time."

In this case, cryptic surveillance causes loose coupling between administrators and front-line staff, since administrators are not able to monitor the tasks and outcomes that are part of service delivery.

3.4.3 Environmental uncertainty, complexity

Orton and Weick (1990) suggest that a fragmented external environment that exposes the organization to complex and diverse stimuli can cause loose coupling. Loose coupling is seen as a response to environmental complexity and uncertainty since, as Scott (1985)

argues (p. 603), "loosely joined structural elements are seen as highly adaptive to systems confronting heterogeneous, conflicting, and changing environments." A loosely coupled structure may be effective at dealing with uncertainty and complexity since individual subunits are more autonomous and are free to rapidly adjust to changes in their specific circumstances (Aldrich 1979). Lei et al. (1996, p. 502) illustrate this point by discussing how advanced manufacturing technologies can transform organizations, but that a loosely coupled organizational structure is needed in order to quickly adapt to complex and changing market pressures.

Hansenfield (1983, pp. 154-155) points out the relationship between organizational structure and environmental stability when discussing task perceptions, which he relates to environmental factors, in human service organizations. "In general, the greater the clarity, predictability, and efficacy of the task perceptions, the greater the ability of the organization to develop tightly coupled work arrangements—that is, standardized and routinized procedures, explicit evaluation and monitoring mechanism, and hierarchical authority." However, when task perceptions are unclear and unpredictable, "it is not surprising to find that work arrangements are loosely structured."

3.4.4 Incompatible external expectations

Some organizations must reconcile incompatibilities between environmental expectations for organizational behavior and the need to carry out work activities in a competitive and rational manner. These conflicting pressures can lead to the adoption of loose coupling. Meyer and Rowan (1977) state that many organizations rely on adherence to external "myths" for legitimacy, such as public opinion and expectations, laws, standards, and rules. These myths influence organizational structure, since adherence to these myths is essential for legitimacy and survival. However, strict adherence to these externally established myths can be detrimental to an organization's ability to carry out work efficiently and effectively, since myths may be ambiguous and do not necessarily promote rational work practices. For example, (p. 355) "a governmentally mandated curriculum may be inappropriate for the students at hand, a conventional medical treatment may make little sense given the characteristics of a patient."

Meyer and Rowan argue that some organizations reconcile the need to adhere to myths with the incompatible need to carry out work practices that are rational, efficient, and effective by reducing the level of coupling between formal structures and structures that work at the operational level. This allows the formal structures to project an image of compliance with myths, avoids conflicts that can lead to the loss of legitimacy, and frees

operational structures to direct their own activities without oversight. Operational work units become more autonomous, and are not subjected to formal inspection and evaluation by the formal structures, and coordination among units is handled informally.

Hasenfeld (1983, p. 152) supports Meyer and Rowan's claim by stating that human service organizations operate in task environments that are subject to changing pressures from regulatory agencies, interest groups, and service beneficiaries, and that these external pressures are expressed within organizations so that they can demonstrate responsiveness to these constituencies.

> "It does this by pursuing multiple goals and by allocating resources to distinctly bounded clusters of activities that respond to particular interests of demands. Furthermore, the links and ties among these clusters of activities are purposefully made weak and tenuous because of the potential incompatibilities and contradictions among the interests and demands expressed through them. That is, the integrity of the organization and the minimization of conflict among disparate goals is achieved precisely through the loose coupling of the various internal work units."

3.4.5 Professionalism

Professionalism can facilitate loose coupling since professional employees have power to demand increased autonomy from bureaucratic structures. Kouzes and Mico (1979, p. 457) state that "after years of schooling, professionals consider themselves capable of self-governance and believe that they have the expertise to respond to the demands of clients." According to DiTomaso (2001, p. 255), the power of professionals comes from being able to keep others from doing the work that they do through links to the environment such as state licensing, professional organizations, and credentials. These environmental links legitimize the status of professionals and determine normative professional behavior. According to Scheid-Cook (1990), these environmental links make it difficult for the organization to control the work activities of professionals, so loose coupling is adopted between bureaucratic structures and professionals. This loose coupling gives professionals increased autonomy and discretion in carrying out work tasks.

3.4.6 Specialized knowledge, expertise

As pointed out by Brusoni et al. (2001, p.610), "knowledge specialization per se plays a major role in explaining the emergence of loose coupling." DiTomaso (2001) shows that when workers have knowledge and expertise that are highly specialized, supervisors may not have enough knowledge to direct their activities. Knowledge specialization differs from professionalism, since it does not imply sanctioning of work by external professional organizations. Instead, work becomes loosely coupled (i.e. between worker

and administration) because the tasks that must be carried out by the knowledge worker are autonomously decided since they are considered to be the one with the expertise needed to make that determination.

3.5 Effects of loose coupling

A number of researchers have identified organizational outcomes that are associated with the adoption of loose coupling. Of these, the works of Weick (1976) and Orton and Weick (1990) have been particularly influential, and other research has not deviated significantly from their findings.

In this section, I will present an overview of the effects associated with the adoption of loose coupling. I will loosely organize parts of the discussion around Weick's (1976) and Orton and Weick's (1990) work, but will expand the discussion to include more recent findings that have been reported by others. It should be noted that the outcomes I will discuss in this section are not wholly good and are not wholly bad (Firestone 1985, p.5; Weick 1976), and that the utility of many of the outcomes depends on the specific circumstances confronted in the work situation (Scott 1987, p. 254). I will discuss seven outcomes:

- *Modularity*. Loosely coupled elements are self-contained and have few interdependencies.
- *Buffering*. Since loosely coupled elements function autonomously, problems in one element do not impact other elements.
- *Autonomy and behavioral discretion*. Loosely coupled elements are free to use their own discretion in determining their behavior.
- *Sensitivity to environmental stimuli*. Since loosely coupled systems have several distinct "sensors", they are sensitive to environmental stimuli.
- *Adaptability*. Loosely coupled elements are able to adapt to the environments that they encounter locally.
- *Persistence*. Since loosely coupled elements are distinct and autonomous, it can be difficult to institute changes to the system.
- *Effectiveness*. Under certain circumstances, loosely coupled systems are particularly effective at achieving desired outcomes.

3.5.1 Modularity

Orton and Weick (1990, p. 210) suggest that modularity is one of the common effects of loose coupling, and that many researchers see this as a desirable outcome. They point to work by Page-Jones (1980) to illustrate this point. Page-Jones suggests that in the design

of software systems, modularity, which eliminates unnecessary relationships between autonomous elements called modules, is desirable since it reduces complexities within a design and allows modules to be handled as separate units. Sanchez and Mohoney (1996) stress the importance of modular design for complex products, but suggest that this modularity should be mirrored in the organization in order to achieve "strategic flexibility" (p.63). Perrow (1999, pp. 92-93) and Lei et al. (1996) also stress the relationship between loose coupling and modularity, and they point out the relationship between the design and manufacture of complex products, and the need for modular organization to manage work complexities.

3.5.2 Buffering

The concept of buffering—or protection of the system as a whole from problems in elements or subunits—is a commonly discussed outcome of loose coupling. Since subunits in loosely coupled organizations are autonomous and loosely connected to the rest of the organization, "if there is a breakdown in one portion of a loosely coupled system then this breakdown is sealed off and does not affect other portions of the organization" (Weick 1976, p.7). Perrow (1999, pp. 94-95) has a slightly different view of buffering, and focuses in part on the flexibility and adaptability of loose coupling as a means of circumventing catastrophic accidents:

> "In tightly coupled systems the buffers and redundancies and substitutions must be designed in; they must be thought of in advance. In loosely coupled systems there is a better chance that expedient, spur-of-the-moment buffers and redundancies and substitutions can be found, even though they were not planned ahead of time."

Kmetz (1984) describes *information buffering*, a different type of buffering that can occur as the result of loose coupling. When work is loosely coupled, and parts of the organization operate in an autonomous, modular fashion, they may develop information buffers, or local repositories of information that support autonomous work. Information buffers are not shared with the rest of the organization. In Kmetz's study of workflows on U.S. Navy aircraft carriers, he states (p. 272), "buffers can be specific to processes in the workflow or to members of the organizations." He also points out that information buffers (p. 272), "are used at the discretion of those having access to them, and their very existence can be denied, if necessary."

3.5.3 Autonomy and behavioral discretion

In loosely coupled systems, the elements are autonomous and have discretion in determining their own behavior (Aldrich 1979, p. 326). Horne (1992, p. 90) quotes Tyler

(1987) who claims that in loose coupling, "organization is approached through the loose connections between 'stable sub-assemblies' which retain their identity and a good deal of autonomy at all times." Perrow (1999, p. 92) elaborates on this idea by stating that loose coupling "allows certain parts of the system to express themselves according to their own logic or interests. Tight coupling restricts this."

Weick (1976, p. 7-8) suggests that the behavioral discretional that is seen in loose coupling can lead to an increased sense of efficacy in workers, and Orton and Weick (1990, p. 215) suggest that this leads to satisfaction with the work setting. However, other findings contradict these claims. For example, Lorsch (1973, p. 141) suggests that, "individuals in a less formalized organization with more influence over decisions and working for a participatory leader would work more effectively if they preferred more autonomy and did not prefer strong authority relationships. Persons in more highly formalized organizations, where influence was more centralized and leadership more directive, would be more likely to feel competent only if they felt comfortable with more dependent authority relationships." Similarly, DiTomaso (2001) outlines a number of problems that are encountered by autonomous knowledge workers, such as reduced socialization.

3.5.4 Sensitivity to environmental stimuli

Weick (1976, p. 6) indicates that one of the major advantages of loosely coupled systems is that they have a "sensitive sensing mechanism." Loosely coupled systems are able to "know" the environment better than more tightly coupled systems since they have a higher number of diversified and autonomous elements which serve as "sensors." Staber (2002, p. 418) argues that this benefit is often seen when loosely coupled systems operate in uncertain environments: "When knowledge is tacit and the application possibilities of new knowledge are unclear, loose coupling raises the chance that at least one organizational element is exposed to the environment in ways that contribute to system adaptation." Brusoni and Prencipe (2001) support this claim by showing that in companies that manufacture complex, multitechnology products, loose coupling within the organization allows organizational elements to focus on new innovations and advances in knowledge (available through exposure to the environment) in their area of expertise.

3.5.5 Adaptability

One of the effects of the flexibility seen in loosely coupled systems is that each autonomous element is able to adapt to the situation that it encounters locally. Rubin

(1979, p. 212) equates flexibility with "loose structure", and Horne (1992, p. 97) points out that "adaptability requires loosening." Lutz (1982, p. 653) supports this claim by stating that several conceptual models of organizations indicate that, "organizations that permit considerable flexibility in the behavior of their subsystems are better able to adapt and survive." Weick (1976, p. 6) suggest that the autonomy of elements in a loosely coupled system allows individual elements to adapt to local contingencies, and the loose coupling between elements allows this to occur without affecting the system as a whole. Scott (1987, p. 254) points out that this allows "simultaneous adaptation to conflicting demands." However, Scott (1987, p. 254) also cautions that "whether looser or tighter coordination or coupling is adaptive for the organization depends on the specific circumstances confronted, and is also a matter for investigation, not prejudgment."

3.5.6 Persistence

Persistence, which refers to stability and resistance to change, has been identified as a common outcome of loose coupling (Orton and Weick 1990; Weick 1976; Glassman 1973). Since administrative elements may be loosely coupled with operational elements (e.g. Meyer and Rowan 1977; Scheid-Cook 1990), it is often difficult to institute changes throughout a loosely coupled system from the administrative level (Horne 1992). Spender and Grinyer (1995, p. 909) contend that changes are possible in loosely coupled systems, but they tend to be adopted slowly: "tight coupling leads to punctuated changes while loose coupling makes for more gradual changes." March (1978) takes a more extreme view of administrators' abilities to change loosely coupled educational systems. Firestone (1985, p.4) quotes March (p. 219) who states that, "changing education by changing educational administration is like changing the course of the Mississippi by spitting into the Allegheny."

3.5.7 Effectiveness

One of the main advantages of loose coupling is that under certain circumstances, it allows systems to achieve certain desired outcomes more effectively than more tightly coupled work arrangements. Loose coupling has been identified as an effective approach for achieving five types of outcomes. First, it is useful in reconciling incompatible expectations between external myths and operational units (Meyer and Rowan 1977; Scheid-Cook 1990). Second, it can help reconcile internal conflicts between administrative units and professionals who expect to function with significant autonomy (Kouzes and Mico 1979; DiTomaso 2001). Third, it is considered an effective approach for dealing with complex and unpredictable environments (Perrow 1999; Aldrich 1979).

Forth, since coordination, communication, and administrative oversight are usually minimized, it reduces the costs and difficulties required to coordinate work (Sanchez and Mahoney 1996; Scott 1987, p. 254; Weick 1976, p. 8). Fifth, recent research suggests that loosely coupling may foster innovation at the operational level (Damonpour 1987; Brusoni and Prencipe 2001).

3.6 Summary of loose coupling in organizational research

Organizational research provides important insights about loose coupling that are relevant to the design of CSCW systems. In previous sections, I discussed the major themes that are seen in the literature. In this section, I summarize the major points from the discussion:

- Social systems can be described as open systems.
- Open system are made up of elements, and elements can have different levels of granularity such as individual, workgroup, department, organization.
- Open systems dynamically interact with their external environments, and develop structures to deal with significant environmental influences.
- Loose coupling describes structure and relationships in open systems. Elements are loosely coupled if they are distinct and responsive, but share few or weak interdependencies.
- Loosely coupled elements usually have minimal coordination requirements.
- Loose coupling may be caused by a number of factors, which can include:
    - Prior socialization
    - Cryptic surveillance
    - Environmental uncertainty, complexity
    - Incompatible external expectations
    - Professionalism
    - Specialized knowledge, expertise
- A number of organization outcomes, or effects, come about as the result of loose coupling, including:
    - Modularity
    - Buffering
    - Autonomy and behavioral discretion
    - Sensitivity to environmental stimuli
    - Adaptability
    - Persistence
    - Effectiveness

In the next part of this paper, I will discuss how loose coupling concepts have been used in CSCW literature, and I will survey design approaches that have been used to support loosely coupled collaborators.

4. LOOSE COUPLING IN CSCW

Loose coupling concepts have been adopted in CSCW literature, but they have been applied differently than in organizational research. In CSCW, loose coupling concepts are most often used in two ways. First, they are used to describe collaborative relationships between workers. Second, they are used to describe the level of collaboration that is supported by CSCW applications.

Unlike organizational research, CSCW research commonly overlooks the complex organizational and environmental factors that can influence coupling patterns. Little attention has been given to the underlying reasons that groups and organizations adopt loose coupling. Similarly, researchers have not investigated how the introduction of CSCW technologies impact complex coupling patterns, and how specific design approaches interact with social and organizational aspects of loose coupling.

In spite of the current focus of CSCW research, a number of studies have been carried out that provide some guidance on design for loose coupling. This research considers the collaborative relationships between individuals in groups, and the role that CSCW technologies can play in supporting communication and coordination between workers. In the next sections, I will discuss these studies. I will organize the discussion around the following high-level themes:

- Definitions of loose coupling in CSCW
- Factors influencing the adoption of loose coupling
- Design approaches for loose coupling

4.1 Definitions of loose coupling in CSCW

The terms “loose coupling” and “loosely coupled” have been used in CSCW literature to describe relationships between different types of elements. These include:

- Connections between groupware components (Parnes et al. 1997 p. 169; Ellis 1997 p. 416)
- Relationships between applications (Grønbæk et al. 1993, p. 344)
- The level of collaboration supported in CSCW applications (Haake and Wilson 1992; Dewan and Choudhard 1991; Greenberg and Roseman 1996)
- Relationships between work groups and the rest of the organization (Egger and Wagner 1992)
- Relationships between individuals (Nomura et al. 1998)
- Relationships between members of a group (Gräther and Prinz 2001, p. 252)
- Relationships between teams (Grinter et al. 1999)

While loose coupling terminology has been applied in different ways, the intended meanings are generally the same—to describe loose connections between distinct elements.

The formal definitions that CSCW authors have given for loose coupling focus on relationships between people. For example, according to Begole et al. (1999, p.98), "The degree to which collaborators work closely together or independently is referred to as tight versus loose coupling." Grinter et al. (1999) provide a similar but more descriptive definition. They suggest that loosely coupled work is carried out relatively independently of others, and it requires a reduced level of communication. Tightly coupled work is more interrelated, and requires more communication and coordination.

Olson and Teasley (1996) provide more formal definitions for loose and tight coupling. Their definitions emphasize two dimensions of work: the required response time, and the required level of interaction (p.422):

> "At one extreme, tightly coupled work involves two or more people whose work is directly dependent on each other, and their work typically involves a number of interactions to complete the task. Immediate interaction helps them to communicate clearly or to negotiate some resolution…In tightly coupled work, 'showstoppers' occur when people cannot communicate directly and promptly."
>
> "At the other extreme, loosely coupled work is work in which 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."

Edwards and Mynatt (1997) describe "autonomous collaboration", a term which they credit to Kolland (1994), which might be characterized as a special case of loose coupling (p. 218):

> "Autonomous collaboration is characterized by periods in which groups of users work independently on a loosely-shared artifact. These users then come together for periods of tightly-coupled sharing to integrate the disparate work done by collaborators. Coordination and comprehension of parallel, independent efforts necessitates awareness of current and past efforts among users."

As an example of autonomous collaboration, Edwards and Mynatt (1997) point to group writing, where writers each take responsibility for a section of the paper and work on it independently. Writers periodically collaborate in a tightly coupled fashion in order to merge their work, to divide tasks, and to develop new plans.

4.2 Factors influencing the adoption of loose coupling

CSCW literature provides a different view of the factors that shape the adoption of loose coupling than is seen in organizational research. Organizational research focuses on the organizational and environmental factors that lead to the adoption of loosely coupling.

However, these issues receive minimal attention in CSCW. Instead, CSCW research usually focuses on temporal and spatial distributions, and how they influence the level of collaborative coupling that is seen between workers.

4.2.1 Organizational and social factors

CSCW research often overlooks the underlying organizational and social factors that facilitate the adoption of loose coupling. Some researchers have briefly reported on these issues. However, these factors still have not been explored in-depth, and attempts have not yet been made to consider the implications they have for the design and acceptance of CSCW applications.

Several researchers have discussed organizational factors that contribute to the adoption of loose coupling. For example, Grudin (1994) suggests that some organizations are intentionally structured to reduce collaboration between workers. Similarly, Grinter et al. (1999) show that organizations adopt different coupling patterns depending on work interdependencies and on the physical relationships of workers and workgroups.

Other researchers have suggested that social issues can influence the level of coupling that is seen between collaborators. Cockburn and Jones (1995) suggest that social factors can discourage collaboration between workers, regardless of the supporting mechanisms. As an example, they state that personality clashes between workers can make collaboration burdensome. Bradner and Mark (2002) point out that social issues influence users' willingness to collaborate when they are separated by physical distance (p. 234): "the ability to persuade another and the willingness to initially cooperate decrease with distance while deception of another person increases with distance."

4.2.2 Temporal and spatial factors

In CSCW literature, loose coupling is often portrayed as a side effect of temporal and spatial factors that interfere with workers' abilities to collaborate. Researchers have identified three common temporal and spatial distributions that can lead to loose coupling: physical distribution of workers, schedule variability between workers, and worker mobility. Since these factors can increase the effort needed to collaborate, workers may adopt autonomous and loosely coupled work styles. For example, when workers are physically distributed and do not see each other face-to-face, it is more difficult to communicate and to coordinate work, so loose coupling is often adopted to minimize overhead.

In the next three sections, I will discuss three temporal and spatial factors that can cause loose coupling:

- Physical distribution
- Schedule variability
- Mobility

4.2.2.1 Physical distribution

In CSCW literature, researchers have shown that collaboration frequency and quality is associated with the physical proximity of collaborators. This is illustrated by Kraut et al. (1988) in a study of collaboration practices between researchers. Their findings show that physical proximity increases the likelihood of collaboration between researchers, in part due to increased opportunities for unconstrained and opportunistic communication. They also point out that proximity allows face-to-face interactions that use multiple sensory channels, which result in high quality and more intense collaboration. Finally, they suggest that a significant amount of the communication that occurs between co-present researchers is not planned, and would not occur if it had to be planned.

The decreased collaboration that is associated with physical distribution can lead to loose coupling between workers. Olson and Teasley (1996) point out that when remote work is difficult to coordinate, it is often restructured to be loosely coupled. They describe an instance (p. 425) where a worker who was physically separated from the rest of the team was allowed to pick his work assignments. The worker selected work that was "cleanly partitionable", since this minimized ongoing coordination demands. In a discussion of organizational structure in research and development (R&D) work, Grinter et al. (1999) equate co-location with tight coupling and high communication requirements, and physical distribution with a loose coupling and reduced communication requirements.

4.2.2.2 Schedule variability

When workers maintain different work schedules, it can be difficult for them to collaborate in real-time. This schedule variability can facilitate loose coupling, since workers may have to expend extra effort to communicate and to coordinate work (Pinelle and Gutwin 2002). While it still may be possible to overcome schedule variations with formal appointments and meetings (Bellotti and Bly 1996), the extra coordination costs can discourage the routine flow of information between workers (Pinelle and Gutwin 2002).

Three major types of schedule variability have been discussed in CSCW literature. First, workers may have different "work rhythms", and they may carry out different tasks at different times (Begole et al. 2002; Reddy and Dourish 2002). These variations can make it difficult to establish common times when workers can collaborate (Begole et al.

2002). Second, workers may work in shifts, and one worker may begin the work day when another worker ends his or her work day (Kaplan 1997). Third, workers may work out of different time zones, and may not work during the same hours (Begole et al. 2002).

4.2.2.3 Mobility

When workers are mobile over a wide area, variations in workers' physical locations and schedules can introduce collaborative difficulties that facilitate loose coupling between workers. For example, Pinelle and Gutwin (2002) show that in mobile home care teams, workers have difficulties communicating and coordinating work with other mobile workers. They suggest that these difficulties partially contribute to the adoption of a loosely coupled, autonomous work style. Similarly, Fagrell et al. (2000) point out that mobile teamwork requires autonomy to deal with local situations, but that work interdependencies may exist that require collaboration.

Several collaboration difficulties can contribute to loose coupling between mobile workers. Since physical location is a changing dimension in mobile work, it is difficult for workers to stay aware of others' locations and availabilities (Fagrell et al. 2000; Belotti and Bly 1996), which makes it difficult for workers to communicate and coordinate work (Belotti and Bly 1996). In mobile groups, workers may have more opportunities to see each other face-to-face since they do not work out of distributed fixed locations. However, the variability in time and location seen when workers are mobile over a wide area can make it difficult to establish any type of intentional synchrony, even when technologies are utilized (Brown and O'Hara 2003).

Pinelle et al. (2003) suggest that technical barriers can also play a role in the adoption of loose coupling between mobile workers. They suggest that the current technical constraints seen in mobile computing favor loosely coupled work. Support for tight coupling, which often requires synchrony between workers, is difficult to achieve when workers are mobile over a wide area due to interference and intermittent access to wireless networks. However, loosely coupled work practices that allow partitioning of work tasks, clear ownership of data and artifacts, and asynchronous collaboration reduce the need for real-time coordination and communication, and are well-suited to the unreliability of mobile networks.

4.3 Design approaches for loose coupling

CSCW researchers have investigated design for loose coupling. They have proposed general system design approaches and have also made suggestions about how specific system features should be implemented. Most of this work focuses on improving the

quality of collaboration between individuals in groups by providing support for communication, coordination, and awareness. However, many of the issues that organizational researchers have explored are overlooked in CSCW, including the social, organizational, and environmental aspects of work, and CSCW literature does not provide guidance on how systems should be tailored to support and accommodate these factors.

In the next sections, I will survey CSCW design literature, and will discuss design approaches that have been used in systems that have been developed for loosely coupled workers. I will begin by discussing general approaches that have been used in system design, and then I will discuss research that suggests how specific interactive and collaborative features should be designed for loose coupling.

4.3.1 General system design

CSCW applications that have been developed for loosely coupled collaborators use a range of high-level design strategies. Some designers attempt to change loosely coupled work patterns by introducing tools that increase awareness, communication, and coordination between workers and that lead to tighter coupling. Others provide support for mixed collaborative styles, where variable coupling styles are supported. Finally, others accommodate schedule variability by supporting asynchronous collaboration.

In the next three sections, I will discuss the different general design approaches that have been used to support loosely coupled workers. I will discuss the following approaches:

- Support tighter coupling: real-time CSCW
- Support mixed coupling styles: strict and relaxed WYSIWIS
- Accommodate schedule variability: asynchronous CSCW

4.3.1.1 Support tighter coupling: real-time CSCW

One common approach for designing collaborative technologies to support loose coupling is to provide workers with real-time tools that facilitate tighter coupling. This approach is usually used to address collaborative difficulties that arise when workers are physically distributed between different worksites (Erickson and Kellogg 2000). Real-time CSCW tools attempt to overcome these difficulties by supporting a more natural style of collaboration between physically distant workers (Gutwin and Greenberg 1999). In general, this approach is not practical for dealing with mobility and extreme schedule variability since real-time tools require workers to schedule common times for using the shared application.

Since real-time CSCW applications constrain workers' schedules and can introduce additional interdependencies between workers, using these applications can lead to a more tightly coupled style of work (Ellis et al. 1991). To work together using real-time CSCW tools, workers must arrange their schedules so that all team members are at their computers at the same time so that they can participate in the supported tasks (Pankoke-Babatz and Syri 1997). Additionally, many real-time CSCW tools tighten coupling by allowing workers to inspect others' work, and by supporting tighter coordination than might otherwise be seen in distant work. For example, real-time CSCW applications often focus on tasks that require fine-grained coordination, such as multi-person editing tasks (e.g. Olson et al. 1993, Streitz et al. 1994). Coordination support is often provided using telepointers and other features that help users to maintain a detailed awareness of others' activities (Gutwin et al. 1996; Gutwin and Penner 2002).

A number of real-time CSCW tools have been developed to allow collaboration between physically distributed workers. Groupware toolkits such as GroupKit (Roseman and Greenberg 1996), COAST (Schuckmann et al. 1996), and Rendezvous (Patterson et al. 1990) are all intended to help developers build real-time CSCW applications. Additionally, many CSCW applications provide features that allow tighter collaboration across a distance such as videoconferencing tools (e.g. Okada et al. 1994), audioconferencing tools (e.g. Rodenstein and Donath 2000), shared whiteboards (e.g. Streitz et al. 1994), and shared editors (Olson et al. 1993).

4.3.1.2 Support mixed coupling styles: strict and relaxed WYSIWIS

Another CSCW design approach for loosely coupled workers uses real-time collaborative support but allows workers to select between a tightly coupled operating mode and a loosely coupled operating mode (e.g. Begole et al. 1998). This is similar to the approach discussed in the last section—it attempts to bridge physical distances between workers by providing support for real-time collaboration and shared work. However, this approach gives workers greater flexibility in determining their level of collaborative coupling by allowing them to select an operating mode that is appropriate for addressing a given work situation.

Tightly coupled and loosely coupled modes are commonly implemented using two user interface approaches: strict WYSIWIS and relaxed WYSIWIS, respectively (What You See Is What I See — Stefik et al. 1987). Strict WYSIWIS mode forces users to share a common view of the shared workspace. For example, if one user scrolls the view of a shared document, all other users' views scroll as well. Since this approach limits users'

autonomy, it is usually called a tightly coupled operating mode (Schuckmann et al. 1999; Baecker et al. 1994). In a relaxed WYSIWIS mode, users can individually control their views without changing others' views. Since this allows more autonomy, it is usually called a loosely coupled operating mode (Schuckmann et al. 1999; Baecker et al. 1994).

A number of real-time groupware applications that have been discussed in CSCW literature allow workers to determine their "coupling mode" (e.g. Haake and Wilson 1992; Dewan and Choudhard 1991; Greenberg and Roseman 1996; Beaudouin-Lafon and Karsenty 1992). For example, Greenberg and Roseman (1996) describe GroupWeb, a shared web browser that provides two levels of view coupling. Users can either work with a "slaved view" where they must view the same webpage, or can view pages independently using the loosely coupled mode. Similarly, Baecker et al. (1994) describe SASSE, a collaborative text editor that provides two view modes. SASSE allows workers to work on different parts of the document using the loosely coupled mode; tightly coupled mode forces workers to share a common view of part of the document.

While this mixed coupling approach is in common use, it is worth noting that loosely coupled WYSIWIS modes do not necessarily support loose coupling as it is described using CSCW definitions (e.g. Grinter et al. 1999; Olson and Teasley 1996). For example, real-time CSCW tools force workers to arrange their schedules so that they can use the application at the same time. This does not accommodate schedule variability between workers, it requires increased coordination, and it subjects work to increased inspection by others, even when loosely coupled mode is used. While loosely coupled mode does allow more autonomy in carrying out tasks within the application than tightly coupled mode, it is still unclear how well loosely coupled WYSIWIS operating modes support the complexities of loosely coupled work.

4.3.1.3 Accommodate schedule variability: asynchronous CSCW

Another CSCW design approach for loose coupling uses asynchronous tools that accommodate schedule variability between workers. This approach is suitable for workers that are physically distributed; for workers that work out of a shared location, but at different times (e.g. shift work); and for workers that are mobile. Asynchronous CSCW applications allow workers to work and collaborate whenever it suits their schedule (Pankoke-Babatz and Syri 1997; Manohar and Prakash 1995), and this approach frees them of the need to schedule common times to use the application, as is seen in real-time CSCW applications.

According to Olson and Teasley (1996), loosely coupled work does not require the same level of timeliness that is seen in tightly coupled work (p.422): "loosely coupled work is work in which people need to be aware of others' activity and decisions, but without the need for immediate clarification or negotiation." Asynchronous CSCW applications accommodate this style of work. These applications usually allow more autonomy than real-time applications (Preguiça et al. 2000; Edwards et al. 1997), and do not force ongoing negotiation with others (Pankoke-Babatz and Syri 1997; Manohar and Prakash 1995). Edwards and Mynatt characterize collaboration that takes place in asynchronous CSCW applications (1997, p. 218):

> "While more loosely defined, asynchronous collaboration has typically been taken to mean collaboration that happens (or can happen) at different times. Group calendars and bulletin boards are the oft-cited examples. Users interact with some shared artifact, and this interaction doesn't necessarily have to happen at the same time. Even if it does happen at the same time, users may not be notified of the interactions of others since updates among users are not as fine grained as in synchronous interactions."

The schedule flexibility seen in asynchronous CSCW applications is usually accomplished using one of several approaches. In one approach, a central server provides client applications with access to a shared virtual workspace that allows users to log in, carry out their work and collaboration activities, and then log out (Pankoke-Babatz and Syri 1997). The artifacts that users create during their work persist and are available to others when they log into the system. This strategy is used in a number of systems including TeamRooms (Roseman and Greenberg 1996) and GroupDesk (Fuchs et al. 1995). On a more limited scope, USENET and bulletin board systems provide a central shared space for group communication.

Other asynchronous applications allow work to be carried out "offline." Since this approach accommodates intermittent network connections, it is often used in mobile computing to deal with variable network access (e.g. Fagrell et al. 2000; Kistler and Satyanarayanan 1992). In this approach, work is carried out on a client application that can be disconnected from a centrally accessible server, and the work is stored until a network connection is available. When network access becomes available, the client and server "synch up." Local work is forwarded to the server so that it is available to others, and the server sends the user information about others' activities. When stored data conflicts with changes that others have made, conflict resolution techniques may be utilized. Several systems use this approach, including Coda (Mummert et al. 1995;

Kistler and Satyanarayanan 1992), Bayou (Edwards et al. 1997; Terry et al. 1995), and FieldWise (Fagrell et al. 2000).

4.3.2 Specific feature design

Several CSCW researchers have suggested design approaches for developing features that support autonomous and collaborative work for loosely coupled workers. Unlike the approaches that were discussed in previous sections, these approaches focus on fine-grained design details and suggest how specific interaction techniques and collaborative features should be realized in CSCW applications. In the next sections, I will discuss three of these approaches:

- Integrate collaboration with features that support individual work
- Support asynchronous awareness
- Support shifts to tighter coupling

4.3.2.1 Integrate collaboration with features that support individual work

Grudin (1994) suggests that groupware designers should not overemphasize the importance of communication and coordination features in design when work is organized to reduce collaboration. He states that when organizations are structured to reduce collaboration, collaborative features will be better received if they are integrated with features that support individual work. Furthermore, he suggests that when collaborative features are added, they should be unobtrusive and should not interfere with workers' abilities to utilize other more frequently used features.

4.3.2.2 Support asynchronous awareness

Several researchers have pointed out that loosely coupled workers need to stay aware of others' activities so that they can identify situations where tighter coupling (i.e. more communication, coordination) is needed (Baker 2002; Olson and Teasley 1996). Much of the research on the provision of awareness information focuses on awareness in synchronous applications (e.g. Dourish and Belotti 1992; Gutwin and Greenberg 1999; Dourish and Bly 1992; Gutwin et al. 1996). However, Edwards and Mynatt (1997) argue that synchronous awareness techniques are not appropriate for loose coupling. Instead, they suggest using asynchronous awareness approaches. Asynchronous awareness has been described as awareness information that persists over time so that it is available to accommodate varied schedules and autonomous work patterns (Neuwirth et al. 1998; Pankoke-Babatz and Syri 1997; Fuchs et al. 1995; Preguiça et al. 2000). Edwards and Mynatt (1997) suggest using techniques such as tracking the history of others' interactions with shared artifacts.

4.3.2.3 Support shifts to tighter coupling

Researchers have suggested that even when workers are loosely coupled, situations may arise that demand temporary shifts to tight coupling. For example, Olson and Teasley (1996, p. 422) report that in their observations of a design team, when conflicts surfaced, loosely coupled work would become more tightly coupled to enable negotiation, clarification, discussion, and agreement. Sakamoto and Kuwana (1993) argue more generally that both types of communication channels are important in cooperative work, and that group tools should support both modes of collaboration. Mandviwalla and Olfman (1994, p. 256) suggest that groupware should support periods of interaction and periods of no interaction.

4.4 Summary of loose coupling in CSCW

In CSCW literature, loose coupling terminology is primarily used to describe relationships between workers. Researchers usually focus on one aspect of these relationships—the collaborative interactions that take place between workers (e.g. Begole et al. 1999; Edwards and Mynatt 1997). When describing coupling relationships, researchers regularly focus on the coordination and communication practices that link workers and the required level of detail and timeliness that is needed for these processes to succeed (Olson and Teasley 1996). Loose coupling is commonly defined as a relationship that allows worker autonomy with reduced coordination and communication demands (Grinter et al. 1999).

In CSCW literature, two causes of loose coupling have been identified: organizational and social factors, and temporal and spatial factors. Organizational and social factors have been discussed (e.g. Grudin 1994, Cockburn and Jones 1995), but only by a limited number of researchers and not in detail. More often, temporal and spatial factors, including physical distribution, schedule variability, and mobility, have been identified as causes of loose coupling (e.g. Kraut et al. 1988; Pinelle and Gutwin 2002; Bellotti and Bly 1996). These distributions interfere with communication and coordination between workers, and can lead to the adoption of loosely coupled work patterns.

A number of general design approaches have been used to support loosely coupled workers. Three of these approaches are: support tighter coupling using real-time systems, support mixed coupling styles using strict and relaxed WYSIWIS, and accommodate schedule variability using asynchronous systems.

Researchers have also identified a limited number of design approaches that describe how specific system features should be developed for loosely coupled workers. Three of

these approaches are: integrate collaboration with features that support individual work, support asynchronous awareness, and support shifts to tighter coupling.

5. PUTTING IT ALL TOGETHER

Currently, a range of design approaches are used to support loosely coupled collaborators, and it is not clear which approaches are best suited for addressing specific social and organizational patterns. The divergence seen in the general approaches that are used in developing CSCW applications (e.g. asynchronous, synchronous, synchronous with mixed WYSIWIS modes) raises questions about how designers can choose the best approach to suit real-world contextual patterns. Similarly, it is not clear how specific system features should be aligned with loosely coupled work patterns. These design decisions are difficult to make given the relatively narrow focus of CSCW research reports, which often fail to discuss the roles that complex contextual factors play in the design process. Additionally, many CSCW reports do not evaluate the impact that systems have on real-world work (Pinelle and Gutwin 2000), making it difficult to gauge how successful given approaches are in supporting workers.

Organizational research suggests a new focus for the study of loose coupling in CSCW. This literature shows that complex organizational and environmental factors can lead to the adoption of loosely coupled work patterns. While these contextual factors are recognized as being important in the design and acceptance of CSCW technologies, they are usually overlooked in CSCW literature on loose coupling. Consideration for these factors is particularly important given the dual influence that technologies and social patterns exert on each other, so it is worth examining the insights that are available through organizational research to develop a better understanding of the issues involved in developing applications for loosely coupled workers.

Organizational research suggests that CSCW developers should focus not just on collaborative interactions between workers, but should also consider other factors that shape the adoption of loose coupling. Even when temporal and spatial barriers to collaboration do exist, there may be other underlying reasons that work is organized in a particular fashion, and focusing on overcoming collaborative barriers alone can cause these subtle issues to be overlooked. For example, Pinelle and Gutwin (2003) show that in home care, worker mobility makes collaboration difficult and infrequent, but the loose coupling that is seen between workers also allows them to flexibly deal with the uncertainty of the mobile work environment. In this case, focusing on collaborative barriers alone might lead to the assumption that tighter coupling would be the proper

approach for addressing collaborative difficulties. However, looking more deeply at other environmental and organizational factors reveals a more complete picture of issues that are important to design and to the acceptance of CSCW technologies by workers.

The divergence seen between organizational research and CSCW research suggests that there may be other biases in the fields that create these differing views. For example, CSCW and organizational research tend to study different types of organizations. Many of the loosely coupled organizations that are studied in organizational research are from domains that afford workers significant autonomy such as professional organizations or human service organizations (e.g. education and health care). These settings are often underrepresented in CSCW research in favor of workgroups that carry out more tightly coupled tasks such as software development or shared editing tasks (e.g. documents, figures, hypertext). This does not mean that professional organizations and human service organizations are inappropriate targets for CSCW research, but it instead suggests that they may deserve more attention than they have received in the past.

Another point of divergence between the fields is the size of the organizational unit that is studied. Much of the organizational research on loose coupling examines organizations from the top down, and considers the relationship between subunits within the organization. In CSCW, research often focuses on design for small work groups, and does not always consider the relationship of those work groups to the larger organization. This difference does not mean that organizational research is irrelevant to CSCW. However, it does suggest that in CSCW, a better understanding of causes and outcomes associated with loose coupling might be better achieved by considering connections that extend outside of the work unit to other parts of the organization.

6. CONCLUSIONS

In CSCW literature, loose coupling concepts have been used to characterize relationships between members of organizations and groups. However, current CSCW design literature provides little guidance on how developers should address the complexities of loosely coupled work. In this paper, I have attempted to take a first step in developing an understanding of design for loosely coupled groups and organizations by surveying literature that covers the social, organizational, and technical aspects of design.

This survey provides promising insights on CSCW design for loose coupling—however, the social and organizational research on loose coupling, and the technical design literature on loose coupling are partitioned between different research communities. This fragmentation means that formal empirical investigations have not yet

been carried out to investigate the implications that the social and organizational findings that are presented in organizational research have for the design of CSCW systems. Some possible questions that warrant future exploration are:

- What strategies should be used when designing features for systems that support loose coupling?
- What are the design implications of the social, organizational, and environmental factors that contribute to the adoption of loose coupling?
- What strategies are commonly used by loosely coupled workers to sustain loose collaboration, and how can those strategies be supported in design work?
- How can support for collaboration be built into tools that support autonomy primarily?
- How can designers determine when the different general design approaches reported in CSCW literature are appropriate?
- What design considerations must be addressed when loosely coupled workers are mobile?

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