# Extending Small Group Theory for Analysing Complex Systems

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**Abstract:** This paper introduces a social psychological theory – Small Groups as Complex Systems – as a contribution to the design of CSCW and CMC systems. Small Group Theory is composed of local dynamics which model the internal view of a group; global dynamics that represent whole group emergent properties; and contextual dynamics that model the influences of the group's environment on its composition, coherence and behaviour. The potential contribution of Small Group Theory to the design of CSCW systems is investigated by model-based analysis of group members, supporting technology, and design principles motivated by the theory.

**Keywords**: cognitive theory, modelling framework, socio-technical systems

## Introduction

Activity Theory (Nardi, 1996) and Distributed Cognition (Hutchins, 1995) have provided insight for informing the design of collaborative systems, but do not provide a detailed model of systems. In contrast, task modelling approaches have been extended for CSCW systems (Van der Veer, Lenting & Bergevoet, 1996), while Cognitive Work Analysis (Vicente, 1999) also provides a model-based approach for design of human activity that takes social and ecological context into account. However, there has been little convergence between task modelling and theory-driven approaches in CSCW. Instead, researchers in CSCW have evolved design principles from a combination of ethnographic study and design exploration (Abowd & Mynatt, 2000; Olson & Olson, 2000). However, such design principles focus on the technology for collaborative systems and tend to ignore the need for socio-technical solutions for collaborative systems.

One of the weaknesses of applying theories to HCI, e.g. Activity Theory and Distributed Cognition, is that design recommendations are indirect, i.e. they require a theory-knowledgeable expert to provide design recommendations. For example, the influence of Activity Theory analysis in design of the exemplar case study for a Coloured Petri Net tool (Bertlesen & Bødker, 2003), while plausibly explained, is not easy to generalise to other domains and examples. Perhaps, given the complexity of phenomena at the social level, it is unrealistic to expect theory to prescribe design in complex systems.

This paper introduces a social-psychological theory that does account for a wide range of phenomena and investigates its power for analysing requirements for the design of socio-technical systems. The theory of Small Groups as Complex Systems (hereafter SGACS theory: Arrow, McGrath & Berdahl, 2000), is a successor to Social Dependency Theory (McGrath, 1993). The paper is structured as follows: SGACS theory is introduced and briefly explained. The use of the theory as an analytic instrument is investigated and limitations of applying it are discussed. Principles are derived from SGACS theory that might be used to influence design of collaborative systems. The paper concludes with a brief discussion of the contributions that social-psychological theories might make to interactive systems design.

## Small Groups as Complex Systems Theory

The SGACS theory comes from a social psychological heritage which takes an eclectic approach of theory synthesis building on research into groups as information processing systems (McGrath, 1998), bringing together 13 streams of social psychology research (Arrow et al., 2000). SGACS theory limits its scope to small groups, i.e. <=20 members. The theory contains a taxonomy of groups, a timeline view of group evolution, intra-group modelling called local dynamics, whole group modelling referred to as global dynamics, and assessment of the environment in contextual dynamics. The theory is based on a set of seven propositions that govern the influences at the local, global and context levels.

The theory classifies groups into task forces (single project, short duration); teams (many projects, longer duration); crews (strong role models for collaboration); and social groups (non-work goals, member-driven collaboration); see Figure 1. A set of dimensions classifies groups according to their duration, goal directedness, and mode of creation (external setup/internal motivation). SGACS theory explains how groups of different types develop over a life cycle of formation, emergence, operation, maturity, senescence; and describes qualities for successful group interaction and pathologies in structure and behaviour that can disrupt achievement of common goals and destabilise the group.

| | external organiser | no external organiser |
|---|---|---|
| Work related goals | teams, task forces, crews | ad hoc task forces |
| Socially motivated goals | social clubs, societies | social friendships, clans |

Figure 1 - Taxonomy of Groups (adapted from Arrow et al., 2000)

The theory is composed of two layers, a bottom-up analysis driven from modelling the composition of groups, and an upper layer of emergent properties that characterise the group as a whole. Contextual dynamics describes the influence of the group's environment on both levels. The lower level, local dynamics, provides an internal view of the group composed of agents, goals, tasks, tools and communication channels. Key success factors include member participation, leadership, authority/hierarchy v. autonomy/democracy, etc. For task forces, formation of a sound task and labour network is important for effective sharing of work, while social relationships are less important given the short duration of the group. In contrast, a member and role network is vital for teams where social relationships are crucial to success. Crews require sound tools and job networks so they can function effectively, employing role knowledge even if individual members change. In SGACS theory, tools refers not only to hardware tools such as computer systems but also to tools as collective knowledge, i.e. shared strategies, procedures and norms which are important ingredients for teams and crews. The group-level, global dynamics view describes emergent properties of whole groups such as social cohesion, motivation, shared beliefs, image, goals, satisfaction of members, effectiveness in achieving tasks. Some concepts and heuristics describe how internal properties of groups might contribute to emergent properties at the global dynamics level. An overview of SGACS theory is given in Figure 2, which illustrates its components and models.

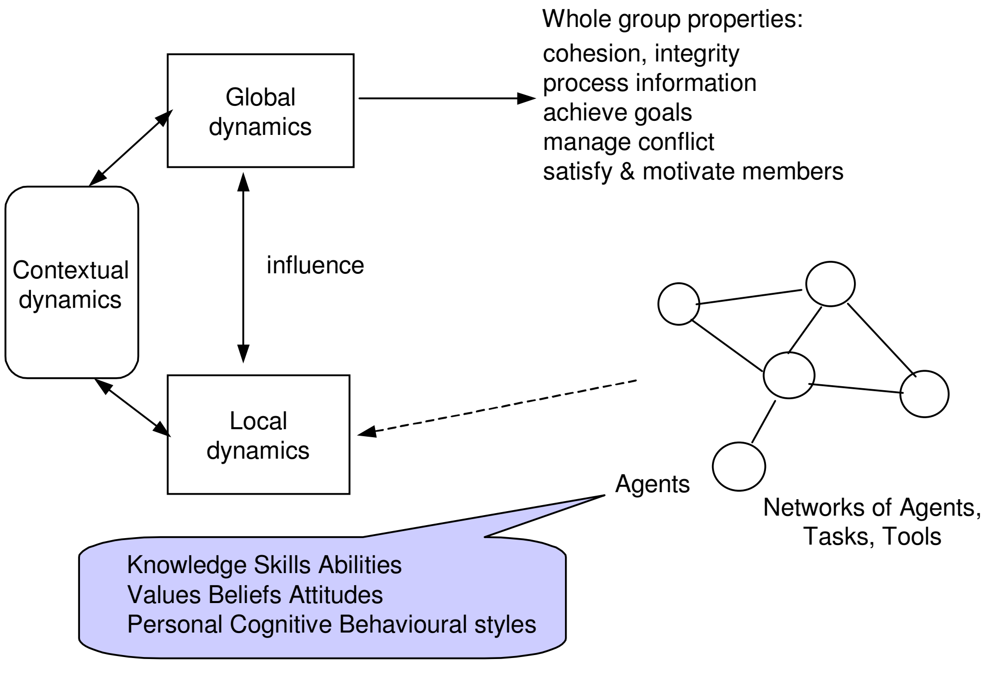


Figure 2 - Overview of the Components of Small Groups as Complex Systems Theory

Clearly, a few paragraphs of description can hardly do justice to a sophisticated and complex theory; however, further partial description is interleaved with a discussion of how to apply SGACS theory, and the reader is referred to Arrow et al. (2000) for an authoritative description.

**Modelling Socio-Technical Systems**

In this section we discuss how analytic techniques could extend SGACS theory to model socio-technical systems, specify requirements for supporting technology and diagnose potential problems in group working. Local dynamics models phenomena which HCI researchers are familiar with: tasks, agents and roles; however, the theory needs to be elaborated to demonstrate how modelling individuals in groups and their work can be used to predict group behaviour and performance.

*Tasks, Agents and Roles:* SGACS theory creates three complementary networks showing the relationships between agents and tasks, tasks and tools, and agents and tools. Tools may be software systems, information or other resources used for completing tasks. A key concern in task-agent-tool network analysis is the level of support provided by tools to the agent for achieving the task. Assessing task-agent-tool networks needs a measure of task-tool fit which could be taken from subjective ratings, combined with usability metrics from evaluation studies. In collaborative systems, even though the task-tool fit for individual roles might be reasonable, support for group integration may be more critical, so a separate group-level analysis of tool support will be necessary. Support for communication, coordination, and collaborative work could be assessed by expert judgement, questionnaires or by evaluation studies. Analysis techniques assess how well a task-goal could be developed using descriptions of supporting tools and agents' qualifications. The i* modelling language provides techniques for reasoning about relationships between task-goals, agents and supporting resources (Mylopoulos, Chung & Yu, 1999; Yu & Mylopoulos, 1994). Although i* has been augmented with socially oriented relationships, such as capability and commitment of agents and trust between them (Castro, Kolp & Mylopoulos, 2002), it does not explicitly consider interactions between agents or properties of whole groups. SGACS theory can supply such concepts via the local dynamics analysis. KSA (knowledge, skills and abilities) analysis could augment the concepts of capability and commitment to assess whether a group has the necessary human resources for a project. However, detailed assessment of how effectively tasks might be carried out by agents and supporting resources implies considerable domain knowledge. Using abstract categories of tasks, combined with appropriate knowledge of requirements and claims, might provide a viable approach (Sutcliffe 2000, 2002); otherwise, human expertise will be necessary for interpreting models. The value of task-agent-tool modelling will depend on the insight gained in analysing pathologies in systems, compared with the expense of creating detailed models.

SGACS theory predicts that the task-agent-tool network should become more integrated over time and that a good fit between tasks, people and technology will enhance group effectiveness. Furthermore, individual goals and roles of group members should concord with the group's objectives. The social aspect of agent interaction could be analysed by studying the channels and patterns of communication between group members. SGACS theory does not deal with communication patterns; however, these could be studied empirically by discourse analysis (Clark, 1996) or simpler measures such as recording messages passed between agents to create network graphs of inter-agent communication frequencies. Pathologies may be posited if certain agents are isolated from communication networks. If a more detailed discourse analysis were carried out, other pathologies in communication patterns, e.g. arguments, disagreement, could be diagnosed. Unfortunately, discourse analysis is time consuming so a more economic approach might be using subjective ratings of communication frequency and effectiveness by each individual with other group members. In summary, task-tool support and communication analysis techniques could predict where problems might arise in cohesion of collaborating groups. In the following section we turn to analysis of individual group member attributes.

*Knowledge, Skills and Abilities:* One of the tenets of SGACS theory is that network integration at the affective level, i.e. trust, social familiarity and friendship, should deepen as the group matures in the formation and operation phase, leading to improved effectiveness. For this analysis, SGACS investigates the knowledge, skills and abilities (KSA) of agents to determine how well the group's human resources fit the needs of the tasks and group objectives. Then the values, beliefs and attitudes of individual members are evaluated, followed by personal, cognitive and behavioural styles. The second set of measures bears on group cohesion, since groups composed of members with very different attitudes and beliefs are less likely to develop the deep shared understanding that is necessary for effective collaboration.

SGACS theory does not specify how KSA analysis should be performed; however, knowledge can be interpreted as domain and task knowledge held by individuals that is relevant to the collective task. Skills may be interpreted in their cognitive sense, i.e. pre-compiled, internalised procedures for carrying out tasks. Abilities can be considered as capabilities or resources that contribute to the collective goal. Hence knowledge and skills are individual-level attributes ascribed to people, based on expert judgement or measures (e.g. skills tests), whereas abilities reflect capabilities of a person's role discerned by expert judgement.

In highly trained domains KSA analysis should show that all personnel have the necessary knowledge and capabilities to carry out their individual and collective tasks. KSA analysis should also show critical weak points in a collaborative system if training has been less than adequate. But deciding just when a deficit in KSA analysis might signal a dangerous flaw is not obvious. Individuals might collaborate to remedy deficits in knowledge and skills; however, ability problems should be easier to diagnose by comparing task requirements and agents' capabilities. KSA analysis, therefore, may complement task, tool and communication analysis for diagnosis of local dynamics problems.

*Values, Beliefs and Attitudes:* SGACS theory predicts that development of a network of personal relationships (member network) and a role network that connects people to shared group norms, resources and procedures, is important for establishing an emergent group-level culture and structure. VBA (values, beliefs and attitudes) analysis may indicate how cohesive a group might be with respect to its members' shared goals, culture and social norms. As with KSA analysis, SGACS theory does not specify how to conduct a VBA analysis. This analysis presents several difficulties. First, values are a nebulous concept usually not directly accessible in interviews, although questionnaires coupled with statistical cluster analysis can detect value-related concepts. Beliefs could be treated as knowledge and information that the core members held to be true about the domain, over the medium to long term. Attitudes can be viewed as a sub-set of this information where stronger valency prevails, so attitudes are construed to affect laden belief. This concurs with theories of emotion which distinguish emotional reactions and hence affective memory in reaction to agents, objects and events (Ortony, Clore & Collins, 1988). A further problem with attitude analysis is tacit knowledge (Rugg, McGeorge & Maiden, 2000). Individuals may articulate an "officially" held attitude at a meeting while holding a possibly contradictory attitude that they only voice in private (Goffman, 1976; Kahnemann & Tversky, 1982). Attitudes and beliefs could be captured by interviews or questionnaires, the latter being more reliable as they reduce the subjective interpretation of interview data. Unfortunately, development of questionnaire instruments takes time and resources to refine an appropriate set of questions from initial pilot studies. Hence capture of VBA data is likely to be time consuming. However, VBA analysis might be able to predict pathologies in group cohesion if mismatches between group members' attitudes and beliefs were apparent. But this would require considerable further extension of the theory to predict which types of beliefs and attitudes might clash.

The next analysis, PCB (personal, cognitive and behaviour) styles, presents even more complexity. Such measures require personality-style inventories to be completed by the group members, e.g. for personality profiles (McCrae & John, 1992) or cognitive styles (Kelly, 1963). Personality testing is a reasonably mature area in psychology with many questionnaire instruments; however, how to diagnose pathological mixes of personal styles in groups is less certain. While PCB data could be collected via questionnaire inventories, it is less obvious how such data could be interpreted. There is some guidance in the personality styles literature about compatibilities between personal styles, but few firm guidelines exist to decide whether a certain mix of personality types would impair collaborative behaviours. Furthermore, interpreting the impact of cognitive styles on group cohesion is even less sure. Hence even though detailed descriptions of groups' members could be made in terms of traits and styles, predicting the impact on global dynamics may well be informed guesswork. It may be more useful to assess individual motivations and how these influence collective goals and group cohesion, but these aspects are not covered by SGACS theory.

**Predicting Emergent Properties**

SGACS theory describes emergent properties of whole groups as global dynamics and indicates that these should be a consequence of local dynamics; however, no procedures are given for establishing global group properties from lower-level local dynamics analysis. Ideally the theory should have predictive power to assess the potential success of groups given a detailed model of their participants. Desirable goals that groups should achieve are to fulfil members' needs, motivate members, process information, generate knowledge and achieve collective goals, while managing conflict, maintaining group integrity and developing agreement to complete group projects. The conjectured influences of local dynamics on global dynamics are illustrated in Table 1. It should be noted that these are hypotheses, not stated explicitly in SGACS. These hypotheses might be realised if effective analytic instruments could be developed and the posited effects were validated by experimental and empirical study. There is clearly considerable further research to realise these aims, but they do illustrate how detailed analysis might reveal emergence properties of groups.

| Analysis treatment | Achieve group goals | Generate knowledge | Maintain integrity | Promote agreement | Motivate members |
|---|---|---|---|---|---|
| Task-agent role capabilities | +++ | +++ | ++ | ++ | + |
| Task-agent-tool support | +++ | +++ | + | + | + |
| Inter-agent communications | +++ | ++ | ++ | +++ | + |
| Task-agent KSA | +++ | +++ | ++ | + | + |
| Agent VBA | ++ | ++ | +++ | +++ | +++ |
| Group goal-agent motivations | +++ | + | +++ | ++ | +++ |
| Agent PCB | + | + | ++ | ++ | ++ |

Table 1 - Implications of local dynamics analysis for group emergent properties (global dynamics) and analysing group performance

Some impact heuristics are posited by SGACS theory to link local and global dynamics. For instance, poor development of the task-agent-tool networks and lack of opportunity to develop close personal relationships indicates poor group cohesion and impaired information processing. Task-agent networks with inadequate knowledge and skills held by groups' members could indicate poor performance and increased errors, possibly leading to social tension within the group caused by inability to achieve collective goals.

VBA analysis might be able to predict potential conflict within groups, assuming that widely divergent beliefs and attitudes are a source of conflict. Conflict may be indicated by clashes between group members' attitudes, values and personality styles, if these are reported candidly in interviews or by questionnaires. Ethnographic or discourse analysis of conversation may reveal member attitudes; however, even if no open disagreements were observed, covert disagreements may be present. Agreement over the goals and achieving the group project is likely to be a function of how well formed the task-agent-tool network was, coupled with how well motivated group members are towards achieving a shared goal. Good motivation and sound task-agent tool support could counteract operational difficulties and tension between group members. A certain level of perturbation might be tolerated in concocted groups since the external formation and authority of the founder might suppress dissent. If the members shared a common motivation then the chance of achieving group projects may be increased. External pressure may also motivate members of the group if there is pressure to conform to a shared view. Analysis of agents' roles, goals and responsibilities may be one approach to evaluate the influence of local dynamics on fulfilling members' needs and motivating members. However, SGACS theory does not make this association explicitly; furthermore, it does not distinguish between individual and organisational-level motivations. This suggests that a motivation analysis needs to be added to the theory.

This section has discussed the potential use of SGACS theory for analysis of socio-technical systems and demonstrates how it might pinpoint potential barriers to success. While SGACS theory places considerable emphasis on contextual dynamics and the influence of embedding context on group structure and behaviour, space precludes discussing these further, although some influences such as the role of external authority on group formation have been introduced.

**Case Study Application**

Space precludes an extensive description of our experience using SGACS theory, so, a high-level "lessons learned" summary of its application is reported in this section. The theory was applied to a case study in local government partnership between organisations in the London Borough of Havering. Data was collected from several interviews with council, police and other members of partnership task groups. Partnerships in the London Borough of Havering involved public and private sector organisations and were instigated in response to government policy set out in the Crime and Disorder Act of Parliament 1999, which aimed to create multi-agency cooperation to tackle crime. Eight task groups were targeted on different crime and community safety concerns. Each task group had members from Havering Police and the council (LBH). Council members were drawn from the appropriate departments, e.g. the Vulnerable Persons Group was attended by officials from the housing, education and social services departments. Other members of the task groups were drawn from the probation service, health authority, private sector organisations and charities.

Membership of the task groups was initiated by the two Community Safety Managers and creation of the groups was a tribute to their persuasive powers. Government organisations had a duty to become members of the task groups; however, several non-government organisations were also recruited as volunteers. Each organisation had to supply at least one individual as a group member. The task groups and community management team were supported by a GIS (geographic information system) owned by Havering Council. The police have an extensive crime reporting system and depersonalised data was transferred from the police system to the GIS, so that the distribution of crimes by type, and offender demographics (age, sex, background, etc.) could be investigated. The council and police maintained websites with limited information on partnerships and community safety. One task group on vehicle crime was analysed in depth. This group was given the mission of reducing vehicle crime in the borough with a particular emphasis on young offenders who had been responsible for most of the problems.

The Vehicle Crime Task Group was composed of four organisations: the borough police force, the local authority, schools and colleges in the area, and a charity which specialised in remedial education for young offenders who had been involved in car crime. The charity matched the cure to the crime by teaching young offenders car maintenance skills. The organisational structure is illustrated in Figure 3.

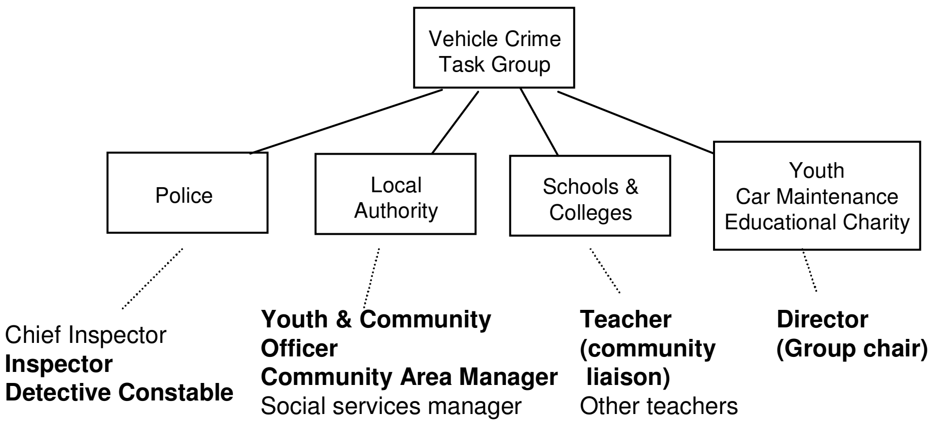


Figure 3 - Organisations belonging to the Vehicle Crime Task Group with the principal group members **in bold,** and other peripheral group members

The core individual members of the group who attended all meetings in the study period were two representatives from the local authority (youth and community officer, community area manager, a police inspector with responsibility for youth opportunities and a community sergeant from the police, one teacher who had community liaison responsibilities from the local colleges, and the chair who was the director of the educational-crime prevention charity. Other peripheral members of the group attended some meetings, including the chief inspector who was one of the group's founders. The task group was composed of four organisations but more were implicit members. For instance, the cooperation of the probation service was necessary to target persistent offenders of car crime, but this relationship was hindered by under-resourcing of the probation service, so they had not entered into a partnership agreement even though this was the intention in the Crime and Disorder Act. Claims and damage information from insurance companies was required for analysing crime patterns but it was not clear if this could be obtained.

According to SGACS theory, the Vehicle Crime Group was a concocted team. Members were brought together by external agency, initially by government policy and more directly by the initiative of the community management team who persuaded non-government members to volunteer their services and motivated government employees (the council, police, education and social services) to participate. The group's objective was to make recommendations and take action to reduce vehicle related crime in Havering. This group fits the SGACS theory's definition of a team since the group's mission can be decomposed into several sub-projects, and it had an anticipated lifespan of two to three years. Local dynamics analysis demonstrated poor coordination in the task-agent-tool network; furthermore the simple e-mail technology employed actually hindered communication due to problems with firewalls in each organisation prohibiting exchange of document attachments. The KSA analysis was limited by the subjects' time to be interviewed and fill in questionnaires to capture skills and abilities; however, a less formal analysis indicated that the group had a reasonable complement of skills and knowledge for the task in hand. We represented the KSA analysis as agents' capabilities in the i* requirements modelling frameworks (Mylopoulos, Chung & Yu, 1999; Yu & Mylopoulos, 1994) which enable simple type-level checking of human skills and abilities against the skills necessary to complete the tasks. The VBA (values, beliefs, attitude) analysis was more problematic to quantify. Consequently we restricted this to assessing individual group members' attitudes toward the collective group goal, rated on a 1-7 Likert scale. This demonstrated considerable differences between individuals in their commitment to the group goals. Global and contextual dynamics revealed that conflicts between organisational loyalties and lack of commitment to a shared goal had serious implications for the group's potential to succeed.

The case study illustrated use of SGACS theory for analysis of socio-technical systems and demonstrates how it can pinpoint potential barriers to success. The key findings from the case study which indicated an unsuccessful outcome of the Vehicle Crime team are summarised as follows:

1. Limited access to information from the police database because of security concerns over depersonalised data. Access was further inhibited by the under-resourced workload of preparing depersonalised data.
2. Poor technology support for collaborative work. This was caused by lack of a shared interactive GIS system, which restricted information access to a slow batch-request approach. The problem was compounded by restrictions on e-mail communication due to the police firewall.
3. The group had inadequate information resources about offender profiles, their behaviour and vehicle crime. This was partly a technology problem and partly a structural flaw in the group which did not have all the local schools or the probation service as members.
4. Infrequent meetings and poor social contact between members of the task group who worked in different locations. This hindered development of a richer task-agent-tool network.
5. Motivation analysis showed that some individual members and their organisations had poor motivation, which did not augur well for completing the group project.
6. Shared goals in the task group, while superficially in agreement, hid considerable disagreement about how to tackle the problem. This hindered information processing, and coordination in the task-agent network.
7. The VBA analysis indicated a considerable divergence in culture and norms between the participating organisations, which suggested that effective co-working may be hindered by conflicting mental models of the problem.
8. The local dynamics analysis showed that formation of an effective role network of members with social relationships and shared knowledge of procedures and norms was unlikely. This is one of the critical success factors for teams.

It was necessary to extend SGACS theory to explicitly model individuals' goals, their motivations, and attitudes towards the collective goal. Furthermore, SGACS theory assumes that groups have a clear membership boundary. We found that we needed to analyse conflicts between individuals' goals, their loyalty to their parent organisation, and attitude and motivation towards the task group. This three-way analysis of individual/group identity exposed many conflicts and resource problems which did not augur well for collective action. Our experience demonstrated that SGACS theory did provide a good conceptual framework for analysis of complex systems; however, it needed considerable extension to add measures and analysis techniques for the variables contained in its models.

## Implications for Design

Most of the problems that may be uncovered by the SGACS analysis pertain to the social system; for instance, the poor construction of a team which did not have the appropriate resources or management to develop a well formed member network. We propose two major contributions which could be developed: first, by task-agent-tool modelling of local dynamics; and secondly, analysis of group composition using properties of individual members to expose potential pathologies in group cohesion and effectiveness. In this section we propose how principles derived from SGACS theory might inform design in combination with modelling approaches.

*Modelling Socio-technical Systems:* Local dynamics modelling may also contribute more directly towards specification of CSCW technology. In i*, functional requirements for task support are modelled as goals, while quality requirements (non-functional requirements) are called soft goals. Goals can be decomposed so functional requirements can be expressed for individuals, the whole group, or within-group collaborations. Tasks become computer, manual or semi-automated procedures that fulfil goals. SGACS theory emphasises that "soft" tools, i.e. shared knowledge of procedures, roles and norms, are a key success factor for local dynamics of teams, so i* models enhanced by the theory could provide a template for specifying requirement of shared artefacts, communication and workflow processes in CSCW. Dependency relationships between agents and tasks indicate the need for task support either targeted at individual agents or collaborations between them. KSA analysis can point out where information and decision support requirements need to be targeted in the task-tool network. Analysis of agent-task-tool and communication networks may point to the need for shared awareness support and knowledge management facilities such as aide-memoire lists of procedures, concept maps of issues discussed at meetings, and workflow tools for allocation of responsibilities among members.

*Design Principles:* To complement modelling socio-technical systems with SGACS-augmented i* models, design principles are proposed based on global dynamics criteria and dependency analysis in task-agent-tool networks. Requirements for collaboration support tools may be expressed as CSCW principles based on global dynamics, such as shared awareness, negotiation support, shared artefact control, etc. The principles may also act as heuristics to critique i* models and collaborative systems designs as a form of expert evaluation.

- *Shared views*: knowledge held by individual group members and their attitudes needs to be visible to other group members. This implies a need for knowledge management and visualisation tools.
- *Collective goal awareness*: the group's collective goal should be communicated to all, with sub-goals and responsibilities of members towards achieving the collective goal. This principle can be supported by shared visualisation of goal trees and progress tracking tools.
- *Support knowledge processing:* information processing and collective knowledge creation should be supported by communication and group decision support systems. Support for this principle will be interpreted in light of the group's collective activity, e.g. managing, design, social activities.
- *Maintain integrity*: by shared goals and information displays, task checklists, goal priorities. This principle may also be supported by shared awareness via social proxies (Erickson & Kellogg, 2000; Viegras & Donath, 1999).
- *Manage conflict*: make decisions and their rationale explicit via design rationale notation or an equivalent. Provide notification, depersonalised as necessary, for group members to express concerns. While we acknowledge that conflict management is a complex topic that requires human negotiation skills to resolve, collaborative technology has a role to play in making the issues visible and shareable.
- *Support agreement*: sorting, prioritising and voting functions, coupled with shared displays of decisions (e.g. gIBIS: Conklin & Begeman, 1988) can help negotiation.
- *Task and agent compatible support*: system functions and communication processes should be based on a local dynamics model of the group's procedures and norms, and support members' behaviour.
- *Relationship support*: the system should support relationship-building appropriate for the group type (crew/team/task force), with shared awareness, representation of shared knowledge and communication.
- *Protect privacy*: allow member contributions to be anonymised according to their wishes. The social identity concepts in SGACS theory indicate a trade-off between shared identity in groups and protecting privacy of their members.

While these principles do not add radically new concepts to CSCW design, they do focus on how technology can support social aspects of collaboration, which constitutes another contribution that SGACS theory adds to design. We could point to other influences such as that the taxonomic view of task forces, crews, teams and social groups may lead to quite different treatment of collaborative support, customisation of member identity, and forms of communication; however, space precludes expansion of these issues.

**Discussion**

The main contribution of this paper has been to introduce the theory of Small Groups as Complex Systems (Arrow et al., 2000) as a new resource for HCI and CSCW design. The strength of SGACS theory lies in its eclectic foundations in social psychology research, and its formalisation of sociological issues with a model theoretic approach. In contrast, Distributed Cognition (Hutchins, 1995) and Activity Theory (Bertelsen & Bødker, 2003; Bødker, 1991) both place more emphasis on human interaction with artefacts in the world. While SGACS theory can account for these issues in the task-agent-tool network, the theory does not place much emphasis on the role of technology in groups. Instead it provides the means of modelling the contribution of technology within a much richer social view of group interaction.

SGACS theory could provide a modelling framework within which concepts drawn from Activity Theory and Distributed Cognition could be expressed. For example, the knowledge-skills-attributes aspect of local dynamics can be adapted to consider the distribution of knowledge in the world that is emphasised in Distributed Cognition. Conflict is a key concern in Activity Theory; it could be analysed to ascertain whether it may threaten group cohesion or, at a more tolerable level, provoke productive exchanges. We argue that HCI needs to synthesise design influences from several theories and that SGACS theory provides a new set of concepts and models that augment previous contributions.

Activity Theory and Distributed Cognition are claimed to influence user interface design, even though authors admit that influence is indirect. We propose SGACS theory as a semi-formal framework which can function productively as a designer's "tool for thought". It functions first as a diagnostic instrument to find potential problems in socio-technical systems, and secondly, as a source of design principles that can be combined with SGACS-i* models to provide critical insight for improving design. Furthermore, it provides a collection of social psychology knowledge that can be applied to CSCW design to augment the perspectives of other theories. Its particular strengths lie in explicit consideration of social relationships that other theories do not consider.

SGACS lends itself as a modelling-based approach for socio-technical systems analysis and design. Moreover, SGACS theory could be augmented with concepts drawn from principles from Distributed Cognition to develop a design method for collaborative systems. The limitation of complex modelling approaches is the effort required to create models in comparison to the design insight gained. As yet no judgement can be given about SGACS theory on this trade-off. Groups in engineering and design domains are more likely to be task oriented teams, which may place more emphasis of the task-agent-tool network analysis in the theory. However, extensions to SGACS theory may be necessary to model the commitment to individuals to a collective goal and how authority might influence group members' motivation and behaviour. Another limitation is the assumptions made when developing theoretical concepts into models and measurable techniques. Considerable interpretation which depends on human judgement is necessary when transforming explanatory theory into prediction about designs.

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