Coordination Breakdowns:
Why Groupware is so Difficult to Design

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Abstract

The complexity of group interaction means that there will be many uncertainties in the requirements for software support tools. Many existing software systems rely on the adaptability of human users to overcome such uncertainties. One of the biggest problems is that existing analysis techniques fail to predict how collaboration will change as a result of the introduction of a new system. In this paper we demonstrate the extent to which group support systems can change an organisation. To address this problem, better theories of how collaboration evolves over time are required, and in particular, what aspects of collaboration are likely to lead to coordination breakdowns. This paper sketches out a model of collaboration based on concepts of shared understanding, conflict and breakdown, and analyses the mechanisms of interaction in the light of this model.

1. Introduction

The psychology of computer users is by no means fully understood. Hence there are many uncertainties in software design, and especially interface design. Many software products succeed not because they are designed to suit their users, but because the users can adapt to suit the software. The question, then, for groupware is whether collaborative work is equally adaptable. We will argue in this paper that groupware design is particularly hard because we do not yet have an adequate framework for understanding how group members adapt to cope with coordination breakdown and conflict.

Collaboration is not easy, even between consenting participants. Effort is needed to maintain the relationship and negotiate the nature of the task, in addition to the effort required to make progress on the task. We have identified two key factors which are largely ignored in the literature, but which are worth further analysis:

- Shared understanding: to what extent do collaborators need to develop and maintain a 'shared understanding'? Furthermore, if we describe two people as having a shared understanding, what claims are we making about the mental representations and cognitive states of those two people?
- Conflict: how do collaborators deal with conflict? Does conflict affect the development of a shared understanding, and if so, how does collaboration proceed even in the presence of conflict?

Both these concepts lie at the intersection of social and cognitive activities. Hence, they can only be adequately explained through a framework which integrates the social and cognitive perspectives. There have been few attempts to develop such a framework. Kuutti and Bannon [1] discuss the need for integrative theories for HCI design. They identify three perspectives, or 'levels' which they term the *work process* level, the *conceptual* level and the *technological* level. They suggest that Activity Theory [2] might provide an integrative framework, as it seems to offer some insight into the way in which artefacts, including software tools, are used in context.

Activity theory shifts the emphasis from individuals and tasks to groups and work practices, but does not account for shared understanding. In contrast, Distributed Cognition [3] treats a group of individuals and the artefacts with which they interact as a single cognitive system. Methodologically, distributed cognition applies micro-level analysis to group interaction to reveal how, for example, knowledge is passed between individuals [4].

However, neither framework adequately tackles a key problem in software design. Introducing a new software system into an organisation changes that organisation. For the software designer, the nature of these changes is hard to predict. Existing analytical frameworks, including activity theory and distributed cognition, offer detailed explanations of group activities, but do not adequately predict how those activities will change in reaction to new software systems.

In this paper, we demonstrate the extent to which a relatively simple group support system can introduce unexpected coordination problems, by considering email. We will then analyse how the various mechanisms of interaction affect the development of shared understanding, and the occurrence of coordination breakdowns.

2. E-Mail & Communication Problems

Electronic mail provides a rich source of data about the effects of group support systems, partially because its use is now so widespread. Because of its simplicity, many users overlook the radical changes it can bring to organisational behaviour. However, various studies [5-9] have revealed the extent of these effects. It is from such studies that we draw our analysis.

2.1. Advantages of Email

Email has a number of obvious advantages over other forms of communication:
- message delivery is fast, even compared to the telephone, as there is no need for both parties to the exchange to be available simultaneously [10];
- contextual information is included automatically. The header of the message contains the message's sender, audience, subject, date of creation, and possibly a reference to a previous message in an on-going conversation. All of this may help the recipient to interpret better the message;
- messages are not ephemeral. Once received, they can be reread, archived or forwarded to other individuals.

Despite these advantages, or in some cases because of them, email causes misunderstanding, and can lead to greater conflict than other forms of communication.

2.2. Conflictual features of email

There are a number of important features of email that contribute to miscommunication:
- lack of status cues: email messages do not convey the status of the sender, nor the social context in which the message is sent [5].
- isolation from audience: Kiesler *et al.* [11] point out that email fails to provide "individuating details about people that might be embodied in their dress, location, demeanour, and expressiveness". Worse still, mailing lists give no indication of the range or number of people on them.
- easy access: anyone can send and receive email, given a terminal and the necessary organisational infrastructure. In particular, it is as easy to send a message to a large group of people as it is to a single person.
- immediacy: composing and sending a message can be combined into a single task, with no opportunity for reflection on the contents or distribution. On receiving an email message, it is easy to compose and send an instant reply. This invites an informality not present in other forms of written communication.
- no regulatory feedback: there is no possibility for adapting the tone or contents of a message in response

to feedback from its recipients. This in itself would not be so much of a problem if email did not have the immediacy and informality described above.
- lack of inflection: email messages are restricted, in general, to ASCII text. This makes it hard to express humour, irony and sarcasm, and to convey the mood of the sender.

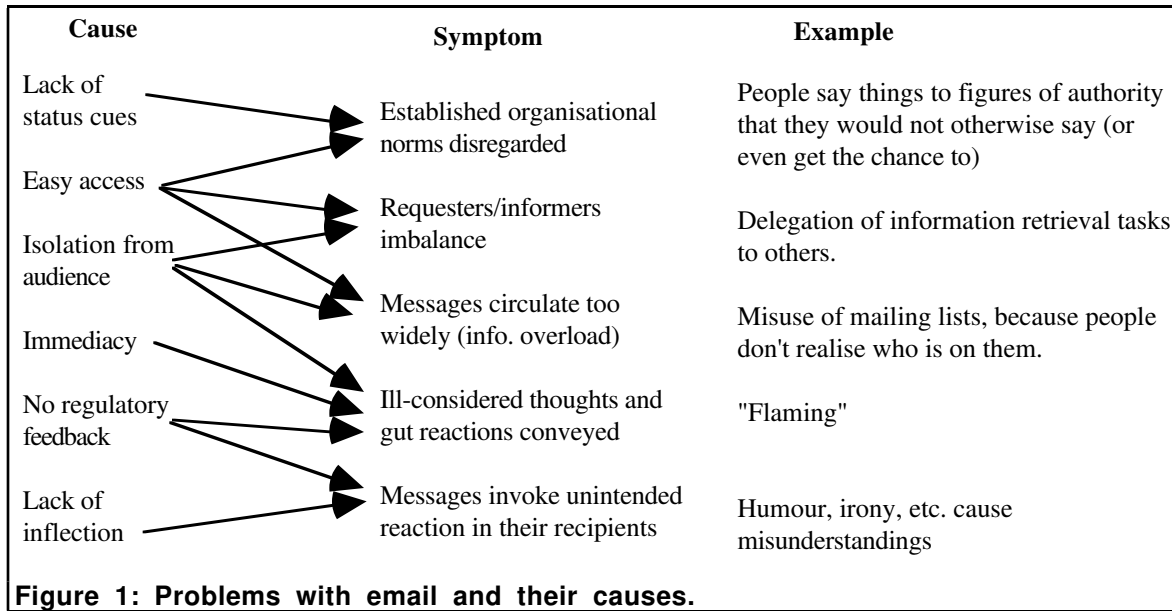These features have led to a number of observed problems:
- established organisational and cultural norms are disregarded. Messages are inadvertently sent across hierarchical, organisational and cultural boundaries where other forms of communication are restricted. Hence, messages might not contain the appropriate diplomacy, deference or tact. Furthermore, there is little clue when this happens. Social blunders and indiscretions often go unrectified.
- messages circulate too widely. A common error is to send a message to too large a set of recipients. Messages aimed at peers are sent to the entire organisation. Messages aimed at people in the same locality get distributed across continents.
- requesters/informers imbalance: email users find it easy to 'delegate' work to others. The tasks off-loaded are often information requests, where the task of retrieval becomes trivial for the sender of the message at the expense of the receiver [12].
- no reflection: the immediacy of the medium encourages people to send messages which, given time to reflect, they would moderate or not send at all. In particular, there is a tendency to be over-hasty in replying to messages that provoke strong emotional reactions.
- humour, irony etc. cause misunderstandings.

2.3. Coping Strategies

Email makes virtually no assumptions about the nature and structure of collaboration, and the ability to send electronic messages to one another offers a number of obvious benefits. The range of problems described above seems inconsistent with the simplicity of the medium.

We contend that none of the available techniques for analysing group interaction or evaluating group support systems could have anticipated these problems. The problems are not so much intrinsic to email itself, but are to do with the way in which users generate expectations about their ability to communicate, based on experience with other media. The problems cannot be solved by ensuring users have accurate mental models of how email works [13], because it is their expectations about effective communication that are incorrect.

Protocols surrounding the use of email have emerged gradually, as coping strategies. These often take a long time to evolve, and rely on the flexibility of the users.

Cause	Symptom	Example
Lack of status cues	Established organisational norms disregarded	People say things to figures of authority that they would not otherwise say (or even get the chance to)
Easy access	Requesters/informers imbalance	Delegation of information retrieval tasks to others.
Isolation from audience	Messages circulate too widely (info. overload)	Misuse of mailing lists, because people don't realise who is on them.
Immediacy	Ill-considered thoughts and gut reactions conveyed	"Flaming"
No regulatory feedback		
Lack of inflection	Messages invoke unintended reaction in their recipients	Humour, irony, etc. cause misunderstandings

Figure 1: Problems with email and their causes.

Examples include "smiley faces" (made of ASCII characters) to indicate that a comment isn't totally serious, and "FLAME ON / FLAME OFF" to bracket comments that are consciously inflammatory. Such devices act as a substitute for other missing cues, and help to ensure that a message is understood in the way it was intended. In other words these devices help users to maintain a shared understanding of the communication process.

3. Definitions

In order to predict more accurately the impact of a new software system on group interaction, a better understanding of that interaction is required. We will first define the terms shared understanding, breakdown and conflict. We will then consider the roles that these play in group interaction.

3.1. Shared Understanding

Two or more people have a shared understanding of a situation if they have equivalent expectations about that situation. By 'expectations' we mean their explanations of the situation and predictions for how it might develop. We assume that such expectations are based on some form of mental model of the situation, although it is not our purpose to characterise such mental models further.

The role of *situation* is crucial. Outside a particular situation, there is no guarantee that a shared understanding will hold, as there is no guarantee that the participants will generate the same expectations in different situations. By 'situation' we mean an episode of interaction and the environment in which it takes place. Extensive definitions of what constitutes a situation can be found in Cody and

McLaughlin [14], who analyse the use of situation in the methodologies of social and cognitive psychology, and Norman [15], who introduces a debate on the importance of situation for theories of cognition.

A shared understanding may be fragile or robust, depending on whether it still holds in different situations. If it is very robust, it may well be the case that the participants have identical mental models. However, we expect that this may be hard to determine. In practice, we do not worry about whether mental models are identical, as we do not wish to make any claims about how the participants derive their expectations. Nor can we expect to observe reliably the application of a shared understanding to different situations, in order to measure robustness. However, we can sometimes detect when a shared understanding has failed to transfer to a new situation, in the occurrence of a coordination breakdown.

Note that shared understanding, as we define it, is distinct from the notion of common (or mutual) knowledge as used in the literature on multi-agent systems [16]. Firstly, common knowledge is usually defined as knowledge that is *known* to be common [17], whereas our definition of shared understanding does not require the participants to know whether they have it. Secondly, we wish to distinguish between *knowledge* as facts or assertions that are generally true about the world, and *models* which are constructed by participants to explain or reason about situations.

3.2. Coordination Breakdowns

It is often the case that a person's expectations about a situation are not borne out. A *coordination breakdown* is a mismatch between the expectations of one participant and

the actions of another. The event that causes the breakdown may be a communication act. The mismatch might be the result of an error of communication or of perception by either party, or a difference in understanding of the situation.

Our interest in breakdown is twofold. Firstly, it provides an analytical tool through which we can study the development of shared understanding, by identifying the limits of that understanding. Secondly, and perhaps more importantly, breakdown itself has an important role in coordinated behaviour, as it allows participants to discover assumptions and conflicts.

Our use of the term breakdown is related to the sense in which Heidegger uses it when discussing tool use[18], to describe occasions when a tool ceases to be transparent and requires conscious consideration. Coordination breakdowns are similar: the breakdown forces the participants to consider explicitly what had previously been assumed: that they share an understanding of the situation.

3.3. Conflict

Conflict is closely related to breakdown. Putnam and Poole [19] define conflict as "The interaction of interdependent people who *perceive* opposition of goals, aims, and values, and who see the other party as *potentially* interfering with the realisation of these goals".

This definition acknowledges that conflict has as much to do with perception and potential as it has to do with action and actuality: a neutral observer may find nothing of substance underlying the conflict, but this does not make the conflict disappear. Easterbrook *et. al.* [20] present a detailed survey of the literature on conflict, drawn from a range of disciplines.

There has been little work on the cognitive aspects of conflict, and few attempts to develop a socio-cognitive perspective. An exception is the work on the role of conflict in collaborative learning [21-23]. This work draws on developmental psychology, to examine the learning outcomes of task-oriented conflict amongst children. However, much of this work merely examines the effect of various situational factors on the learning outcome.

More recently, Joiner [24] has developed a model of conflict in peer interaction which seeks to explain the empirical findings. He categorises conflicts as differences in representations, beliefs, or task focus. The work parallels recent ideas on distributed mental models [25] although the relationship has not yet been explored.

4. The role of breakdowns

We are developing a model of shared understanding based on an analysis of the role of breakdown. In particular, we see breakdown as a crucial element in the
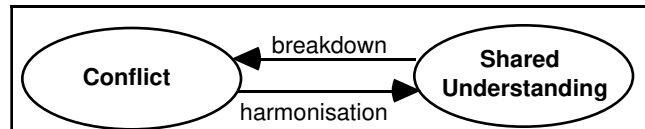

Figure 2: The relationship between shared understanding, breakdown and conflict

discovery of conflicting expectations about group activity. We also see shared understanding as fundamentally limited, in that a group will not normally waste effort developing a shared understanding of situations not yet encountered. Hence, breakdown provides an indicator of the limits of the current shared understanding.

Given this view, breakdown is not necessarily something to be avoided. Rather, it needs to be recognised and managed by the group, so that the members can respond appropriately. This may involve the development of a coping strategy, or it may require some form of explicit conflict resolution. Our eventual aim is to develop tools and techniques that assist with such management.

The relationship between shared understanding, breakdown and conflict is shown in figure 2. The remainder of this paper presents our analysis of the features of group interaction that facilitate development of shared understanding, or which may cause breakdown.

We will distinguish between *mechanisms,* which are implicit or subconscious communicational devices, and *techniques,* which may be applied deliberately by members of a group to achieve certain communicational outcomes. However, the distinction is hazy in some cases.

4.1. Breakdown Mechanisms

Breakdown mechanisms are implicit features of interaction which cause problems either by undermining a shared understanding, or by revealing its deficiencies:

Ontological Drift: As an abstraction passes through different sub-groups of an organisation it is interpreted in terms of each particular community's set of meanings, which frequently do not map onto other groups' sets of meanings [26].

Ontological drift can cause serious communication problems as terms are systematically misinterpreted when used for communication between communities. It is also apparent within a single community over time, especially where that community is evolving its own set of terms.

Learning, forgetting, belief revision: Each individual's understanding changes over time, both as a result of group interactions, and as a result of interactions away from the group. If the participants' models of a

situation evolve during group interaction, the result might be to improve a shared understanding. However, if individuals evolve their models separately, any shared understanding gradually deteriorates unless it is regularly reinforced through communication.

Assumptions and uncertainty: Shared understanding is never complete. In many cases it is minimal. In trying to apply the shared understanding, people deal with the fuzzy areas differently.

This can be illustrated by an example from Suchman [27], in her analysis of a person using a photocopier. The user expresses a goal, such as producing two-sided copies from a journal article. This goal allows the machine to select a set of procedural instructions, but is insufficient to predict what the person will do. The user's actions depend on "the uncertainties of the user's interpretation of the instructions, under particular and at least partially unforeseeable circumstances" (p37). When the user's actions do not match the expected actions, a breakdown occurs which leaves the machine requesting an action, and the user unable to comply, as the action requested appears to conflict with her plan.

Suchman's observations on machine use apply equally to human-human interaction. The difference is that a machine is rarely able to recover from unexpected actions, while another human will almost always adapt to the situation, and repair the shared understanding as necessary.

Boundary objects: These are artefacts shared by different communities, but used for different purposes. Star [28] defines them as "objects that are both plastic enough to adapt to the local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites".

Star observed that scientists are able to collaborate using boundary objects, even though they do not have a good model of each other's work, they employ different units of analysis, and have different goals, and different audiences to satisfy. Examples of boundary objects include indexed repositories, such as specimens in a museum, and maps, which may be suited to a number of different purposes yet tailored to none of them.

Boundary objects may allow communities to share resources, and hence collaborate. However, they may also lead the different communities into developing incorrect models of one another, based on assumptions that others will use the boundary objects in the same way as they do. If expectations of behaviour based on these incorrect models are not met, the result may be breakdown. In other words, there is a danger that boundary objects may mislead the different communities into thinking that there is more commonality than really exists.

Appropriation: This is the process by which one person *appropriates* another person's actions into her own interpretive system. The interpretive system may include goals and procedures of which the other person is unaware.

Newman [29] suggests that appropriation is an important mechanism in learning through social interaction. He gives an example drawn from the domain of teacher-child interaction. A three-year old drawing with crayons may not set out to draw anything in particular, as he is not yet intentionally creating representations of things. If a teacher asks what the drawings are of, the responses are arbitrary, as the child does not intend them to be 'of' anything. However, the child responds to this appropriation of his actions by inventing descriptions, such as "that's a moon". Eventually, he began to talk about "making a house" as he was drawing, anticipating the teacher's interpretive questions.

In terms of the model presented in this paper, appropriation is a breakdown in which one person models the situation differently to the other. Newman's examples only concern expert-novice interactions, where resolution is normally carried out entirely by the novice, who will try to reconcile the unexpected interpretation. For the interactions we are concerned with here, it is likely that the resolution will be carried out cooperatively.

4.2. Breakdown Techniques

Breakdown techniques can be used explicitly by a member of a team to provoke a conflict. The motivation for doing so may be to raise doubts, or even to subvert a shared understanding that is perceived as misguided or harmful. Of course, some of these techniques can also be used merely to express a refusal to cooperate.

Devil's advocate, agent provocateur: These involve deliberate role playing to explore the boundaries of an idea. They can be used to question or even destroy agreement. Normally the intention is to check the validity of an option or seek a better one. However, they can also be used by a person with an unacknowledged perspective to raise it with the group.

Pendell [30] found experimental evidence that deviant behaviour and conflict are normal elements of small group decision making. Deviants were perceived as 'opinion deviants', who presented incompatible views and tested others' opinions and solutions.

Silence, deception, noise, curtness: The communication channel can be manipulated in various ways to interfere with group interaction. The simplest form of manipulation is to fail to communicate. The intention may be to ensure awareness of a disagreement,

or to force a confrontation. Alternatively, the intention may be to manipulate another person's mental models by misleading them. For example, failing to give expected response cues may lead another person to assume there is disagreement where there is not.

Such techniques lead to breakdown by causing inaccurate models of the collaborative process to be developed. However, the intention behind their explicit use is not necessarily negative. For example, they may cause another person to improve his arguments or develop alternative models.

Exerting power: Exerting power has many of the same effects as manipulating the communication channel. Berger [31] points out that power and communication are intricately connected, with most definitions of social power resting upon the ability to produce various changes in behaviour or disposition of others.

Exertion of power leads to breakdown when it is used to subvert or curtail processes of reasoning and argumentation, or when it is used to manipulate the mental models of others. If the exertion of power is unexpected, then the participants' models of the collaboration may need to be revised. If power is regularly exerted, then the shared understanding will come to focus almost exclusively on the power relationship, so that members of the team might never develop adequate models of their cognitive relationship. Also, exertions of power may go unnoticed. For instance, a person who does not believe she is subject to outside influence might adapt her mental models or the criteria for choosing between them without realising it.

Withholding information: This often occurs accidentally in normal work practices. However it can also be used deliberately, to foster dissent. In terms of the model, if one person has information to which others are not privy, there is a specialisation. Furthermore, if others are not aware that the withheld information exists, then their mental models will not include the specialisation, so they cannot accurately predict that person's actions.

4.3. Harmonising Mechanisms

Harmonising mechanisms are the features of interaction which assist with developing shared understanding:

Dialogue rules: Conversation is a cooperative activity, in which speakers and listeners make use of implicit agreements about how conversation works.

Grice [32] set out many of the basics of cooperative conversation. He identifies the *cooperative principle*, by which each conversational contribution is designed to be relevant and clear, and to contain an appropriate amount of information. The speaker intends the hearer to draw certain inferences from an utterance, and the cooperative principle is the implicit mechanism through which this is achieved.

Discourse analysis has identified many implicit rules of conversation [33] which govern, for example, who gets to speak next, and at which point a person can be interrupted (turn taking); and what constitutes a valid response to a particular type of utterance (adjacency pairs).

Gesture, facial expression, eye contact: These are used for constant feedback and as a signalling mechanism. They indicate whether the listener is hearing, and understanding.

A number of studies of collaborative work have examined the effect of the presence or absence of these mechanisms. Heath & Luff [34] report the results of an extended period of naturalistic observation of video telephones. They found that the users act as if they were physically co-present with their conferees. For example, users were observed echoing the postures of their colleagues, a gesture used to indicate likemindedness. Unfortunately, many of the non-verbal cues deployed in face-to-face communication – such as gestures, body movements and gaze behaviour – are apparently not noticed by listeners, thus disconcerting the speakers and degrading the quality of the communication.

Shared focus, shared reference: These supplement communication by providing more cues for the hearer. They also provide anchoring, by linking the communication to external artefacts. In particular, shared historical reference allows the communicants to build on shared experience.

Mutual knowledge: This is related to the use of reference to shared artefacts. Clark and Marshall [17] identify co-presence heuristics, which allow conversants to infer areas of mutual knowledge. Areas assumed to be mutual knowledge include: the entire conversation so far (linguistic co-presence); current and recent shared experiences (physical co-presence); and knowledge that is universal to a community (community membership).

4.4. Harmonising Techniques

Harmonising techniques are the explicit means by which a group of people can develop shared understanding:

External representations (text, diagrams, sketches): These provide an explicit historical record and help focus attention. Note that external representations are not encapsulations of shared understanding, but merely

aids to its development. However, the understanding can sometimes be reconstructed by reviewing external representations.

Norman [35] considers the role of external representations for conveying understanding, giving an example of a person relating the story of a car accident by pushing pencils and paper clips around on a table. He argues that external representations must be supported by an artefact, and that the role of cognitive artefacts is vital in amplifying our ability to communicate.

Abstraction, differentiation, definition, summarisation: These provide points where shared understanding is explicitly checked and discussed. Abstraction is used to ignore detail in order to establish the overall concepts. Summarisation is used by the hearer, both to check that something has been understood correctly, and as an indication of closure on a topic.

Report writing: This forces a group to set out their understanding explicitly. Note that producing a report doesn't necessarily involve resolving any conflicts, as a report is not necessarily univocal. However, whether the report reflects a shared understanding or describes a conflict, the act of setting it out ensures that the situation is explored. At the very least, report writing ensures that the participants are aware of one another's expectations of a situation.

Debate, negotiation, argumentation: These force a group to compare, explain and support their expectations. They provide protocols through which each person can set out their position. They encourage the externalisation of conflicting models by replacing the social stigma normally attached to disagreement with a ritual in which disagreement is expected.

Group Decision Support Systems (GDSS): These support some parts of the argumentation process by allowing quantitative analysis of positions. GDSS are normally based on decision theory, and hence require the group to attach utilities to various criteria for evaluating options [36]. Although the imposed rationality can often cause problems, the setting out of options and utilities can be a useful group exploration exercise.

Problem Structuring Methods: E.g. Strategic Options Development and Analysis (SODA); Soft Systems Methodology (SSM) [37]. These techniques are designed to elicit conceptual models of a complex organisation, in order to make decisions about potential changes. They are characterised by the separate elicitation of different individuals' understandings of the situation.

The descriptions thus elicited are then compared systematically. This process facilitates an explicit comparison of individual mental models. SODA, in particular, uses an explicit theory of mental models, based on cognitive mapping and personal construct theory.

Note that the chief advantage of these techniques is the increased understanding of one another's views, and hence the process is essentially a learning process. The main outcome is increased understanding, and the gathered representations are of secondary importance.

Design Rationale: This is a technique for representing the reasoning involved in design as an argumentation structure. A number of notations have been developed, based on typed hypertext networks. Typically a notation provides nodes such as 'question', 'issue', 'position', and links such as 'supports', 'answers', 'objects to' [38]. Such notations allow a design team to develop an external map of their shared understanding, either during a design process or as a post hoc rationalisation. They are intended to be used by the group together, and hence do not elicit individual models. In particular the elements of the argumentation structure are recorded anonymously.

The use of such tools in a design meeting helps to structure the exploration, and for a group to develop explicitly a shared understanding.

5. Discussion

We have defined shared understanding and conflict, and described some of the mechanisms by which groups move between them. Each condition has advantages:

- Shared understanding provides a basis for communication and coordinated action. Without a shared understanding, participants are unable to anticipate correctly the actions of their colleagues. Communication would require far more effort, as each communicative act may require explanation.
- Conflict provides a stimulus to explore models. This prevents a group stagnating and promotes change. Difficult conflicts may also be the main inspiration for creativity, in that participants are forced to look outside the existing set of ideas for a way forward.

Because each condition has a number of benefits, a productive group will be in a state of flux between them. In particular, shared understanding is not always desirable, because of the effort required to develop and maintain it. Breakdowns reveal where incorrect assumptions have been made about the extent of a shared understanding: until the breakdown, these assumptions served perfectly well. This fits with the observation that mental models are only constructed if they are needed: it is unreasonable to expect a team to develop a shared understanding of all of a range

of possible situations in anticipation of their occurrence.

This analysis does not explain the confusion and uncertainty which often accompany breakdowns. We can account for these by considering the degree to which members of the team are clear about the relationships between their mental models. For example, participants may perceive there to be a shared understanding, whether or not any shared understanding exists. This may lead them to form mental models of how the team will react to particular situations. We term these *team models*.

Team models might be very simplistic, perhaps even not available to conscious reflection, or they might be very detailed, and explicitly shared. For example, all members of the team may have accurate mental models of how the team operates, including where there are differences of perspective, and where there are conflicts. On the other hand, the team may have vague or inaccurate models of the team operation, perhaps leading them to make incorrect predictions about how other members of the team will perform in a given situation.

The degree to which team models are made explicit and shared will affect how well the team can exploit breakdown and conflict. Confusion occurs when a team model is no longer accurate. This may be because the situation has changed, because individual mental models have evolved, or merely because the team model is too vague, or never was accurate.

If new team models are developed rapidly in response to a transition, the confusion will be short-lived. If the transition is deliberate, such as an explicit, successful resolution of a conflict, the team model might be updated immediately. Note that in any case, the new team model may take time to internalise and to supplant existing models. This may prolong the confusion.

One problem with many groupware applications is that they mask occurrences of breakdowns. In the email example, the ability to reply instantly does not allow the recipient time to update their mental model of the other person, through a process of reflection upon the tone and contents of the message. Part of the problem is that expectations for communication through email are based on mental models of other forms of interaction, such as telephone, letter writing and face to face communication. As email does not provide the same cues as any of these other media, breakdowns go unnoticed, and the period of confusion is prolonged.

6. Conclusions

In this paper, we argued that existing approaches to the analysis of group activities do not adequately predict the results of introducing a new software system. To demonstrate the extent of the problem, we discussed how a relatively simple group support system such as email can cause a wide range of problems, as it interrupts established group, organisational and cultural norms.

To address this problem, we have begun to develop a model of collaborative behaviour that focuses on the concepts of shared understanding, breakdown and conflict. In particular, breakdown is seen have having a vital role in group interaction, in revealing the limitations of shared understanding, and revealing hidden conflicts.

We examined the mechanisms of group interaction which lead to breakdown. The purpose of this analysis is not to avoid breakdowns, but rather to improve our understanding of the role that they play in group interaction. We also analysed 'harmonising' mechanisms, which help develop shared understanding.

The model can be used to assist in the development of new groupware applications in two ways. Firstly, the analysis of breakdown and harmonisation mechanisms provides an analytical framework through which data gathered from field studies of group interaction can be interpreted. Secondly, proposed designs for group support systems can be evaluated in terms of support for these mechanisms, to predict how well a group will adapt to it. The model indicates where coordination breakdowns are likely to occur, and therefore where attention must be paid to the way in which the group support system improves or hinders discovery of the breakdown.

Future work will develop the model further, and in particular, examine how it interacts with current work on mental models. Ultimately, we intend to use the model to develop support tools which allow a group to respond flexibly to occurrences of breakdown and conflict, and hence to improve the development of shared understanding.

Acknowledgements

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