A Study of Efficiency in Computer-Supported Collaborative Writing

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SYNOPSIS

In this paper, we present efficiency issues in collaborative writing and investigate how computer systems can support efficient collaboration. We examine efficiency along the axes of effective coordination, absence of breakdowns in the collaboration, and user performance satisfaction. We performed a survey among experienced users of a groupware system to identify (i) the needs that arise from the 'bad fit' between people's perception of an ideal collaboration and their perception of the actual collaboration; (ii) limitations of the system in supporting positive interdependencies among coordination activities; (iii) the relations between quality of output and breakdowns in the collaborative process; and (iv) the relation between forms of collaboration and breakdowns.

Key Words

Collaborative Writing Efficiency, Coordination, Satisfaction, Breakdowns, Quality

INTRODUCTION

Collaborative writing is a major activity that takes place both in academia and other organisations. Documents that are created collaboratively cover a wide range of genres from research papers to legislation documents and committee reports (Mackler, 1987).

Collaborative writing is a complex and difficult process. The collaborators have to manage multiple constraints pertinent to the writing process. In addition, people need to communicate and coordinate the work with their partners who may be distributed in time and space. Although co-authors strive for optimality, they are constrained by their cognitive limitations, lack of sufficient coordination, communication and awareness. So, despite their efforts to avoid breakdowns, they are not always successful. People have employed a variety of conventional technologies (word-processors, telephone, fax, email) in collaborative writing. Although, as research has shown, these technologies change the way people work by offering new ways of working, (Sharples, 1993b) they also introduce problems that increase the complexity and difficulty of collaborative writing, and their contribution to solving communication and coordination problems was limited.

Recent research takes advantage of computer networking and explores new tools for the collaborative writing process. This research emerges as part of the new multidisciplinary field of CSCW (Computer Supported Cooperative Work). There are two main approaches to the design of computer-based systems for collaborative writing. The first approach focuses on understanding the nature of the collaborative writing process and on the development of theories that could guide the design of such systems. The second approach focuses on investigating the effects of technology on the collaborative writing process and group behaviour. In our study, we follow the latter approach to explore the efficiency effects of a particular groupware technology on collaborative writing.

EFFICIENCY IN GROUP WORK

Efficiency is one aspect of group behaviour. The concept of efficiency is a complex and multidimensional one which needs greater elaboration in the context of CSCW (Lea and Spears, 1991). Efficiency has been sometimes explicitly and more often implicitly discussed in the field of CSCW. Different definitions of efficiency have been provided in different

contexts. Based on the interpretation of literature on efficiency of group work we propose the following five types of efficiency:

- Communication: Most frequently efficiency refers to group members ability to communicate data, ideas, feelings in the least wasteful manner (Siegel et al., 1986). Communication efficiency is measured by the amount of communication (e.g. number of messages exchanged) required in group problem solving and the amount of control information that is generated during communication (Novick and Walpole, 1990).

- Resources: Efficiency has been determined in terms of the cost-benefits analysis of resources consumed during the collaboration (Baydere et al., 1993). Resources may include time taken to distribute information among group members, time and effort spent to partition the work and to allocate roles (Finholt et al., 1990), time wasted in inappropriate actions (Petrovic, 1992), and time savings in performing a task in terms of man-hours (Nunamaker et al., 1989).

- Output: Efficiency has also been associated with the quality (Froschle and Niemeier, 1988), (Bowers, 1991) and accuracy (Gabarro, 1990), (Boyle, 1990) of output.

- Process: Efficiency can be defined in terms of the extent to which the collaborators coordinate their work effectively (Sproull and Kiesler, 1991). Another measure related to group process performance is user satisfaction (Hiltz and Johnson, 1990), (Jarvenpaa et al., 1988).

- Fit between technology and work structure: The extent of fit of technology into the work structure determines another dimension of efficiency. The concept of fit has been introduced in structural contingency theory. Structural contingency theory suggests that to

be efficient a work group must fit its technology to the structure of its tasks (Gutek, 1990). Also it has been pointed out that efficiency may depend on the extent that collaborators develop routines for both structured and unstructured tasks that fit into work flow (Putnam, 1983).

Previous research has largely ignored the breakdowns in the collaborative writing process. In the present study, we consider perspectives of efficiency such as user satisfaction, coordination effectiveness, and quality of output. Also, based on interpretation of the existing literature in collaborative writing we have extended the notion of efficiency to encompass the breakdowns that occur in the collaborative writing process. Breakdowns in the collaborative writing process occur when the process is interrupted in a way that has not been anticipated or could not be predicted (Bødker and Grønbæk, 1991), (Winograd and Flores, 1986). Any increase in the number of breakdowns results in decreased efficiency.

THE MUCH SYSTEM

The Many Using and Creating Hypermedia (MUCH) system has gone through six major versions over the past 7 years. The first two versions were developed at George Washington University, one with a relational database management system on an IBM mainframe and another with HyperCard (Rada and Barlow, 1989). Recent versions have all involved a network of UNIX workstations and been based on public domain software (Rada et al., 1991), (Rada, 1991). The latest version uses the Andrew multimedia interface (Borenstein and Thyberg, 1988) and a B-tree database management system. An improved data model provides a foundation for the system. In this new version, several functions have been enhanced and new functions have been added to help authors work collaboratively and retrieve information efficiently.

The main functions of the MUCH system are accessing documents (which includes reading, browsing, and searching), and creating documents which includes planning, writing, and revising on one hand, and organising, finding, and reorganising on the other hand (Rada et al., 1992). Annotation and discussion are complementary features to support the writing process. Some other features to support and monitor collaboration among authors have also been added. It also includes facilities for automatically importing and exporting documents marked up in a number of common formats.

User Interface

The user interface primarily is a split screen with outline in one window and detail or text block in another. The outline window provides a menu of functions provided in the MUCH system. These functions include creation and modification of objects (link, annotation, etc.), a dynamic outline generator, word search facility, interface for drawing package 'xpic', linearisation of document using UNIX document workbench, and viewing of author credit table.

Access to the network for MUCH database is recorded and can be viewed by selecting the 'credit table' option from the menu (see 'Table of Authors and Select Credits' window in figure 1). Each time a node is selected, so that the associated text is displayed, then the person who created the node and whoever updated it get one "select credit". The user is also able to see the "select credits" that a particular text block already received (see 'Node Information' window in figure 1).

Data Model

In the past, different relational and hierarchical models have been adapted to represent the semantic net that underlies the MUCH system (Rada, 1991). In the current version of the MUCH system, the semantic net consists of link objects. Each link object points to a set of nodes which in turn point to a text block. Furthermore, each link object has a set of attribute-value pairs associated with it. These attributes include author, date

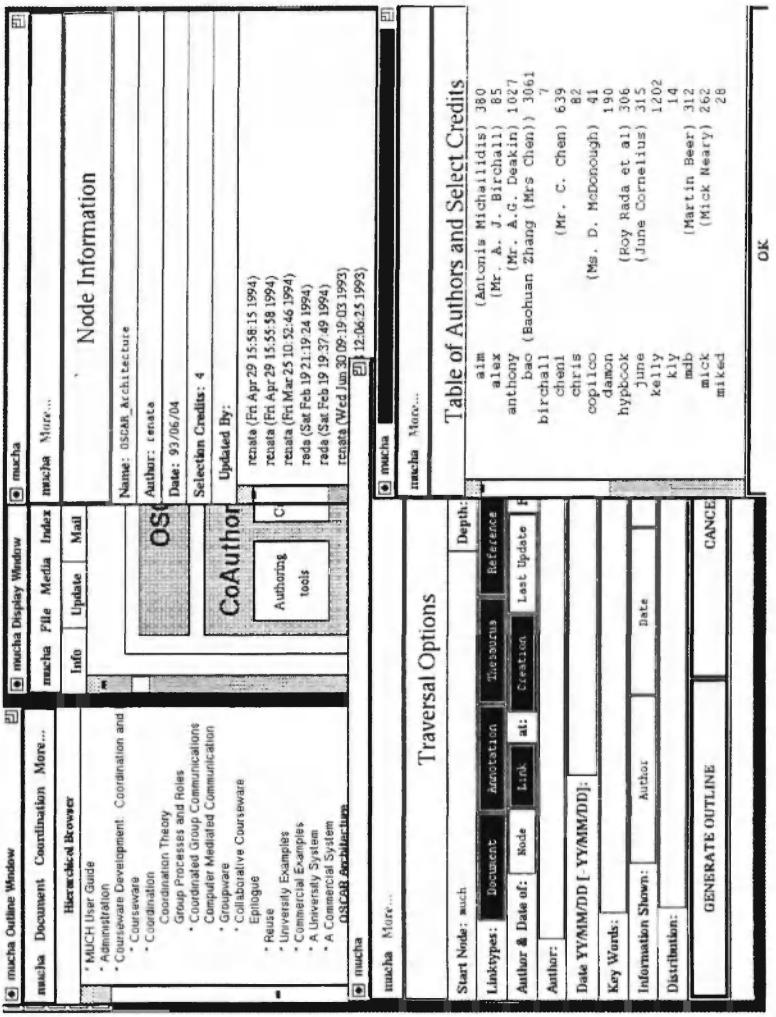

Fig. 1: Screen dump from the MUCH illustrating the outline, text, traversal options, selection credit, and paragraph information windows.

of creation, link-type and phase. The 'phase' attribute tells us whether the link object was created in the writing, or annotation phase, or if it is a thesaurus term, or reference term. A text block is a unit of information which in our case is one or more paragraphs.

Functionality

The create mode may involve three different stages: planning, writing, and revising. The order in which these three phases can be performed depends on the author's writing strategy. The author may create nodes and link them to the graph underlying hypermedia. The create mode also supports the process of annotating documents or other annotations. An annotation can be annotated.

The access of information may include reading, browsing, and searching. The user can manually fold/unfold the outline to find and then select a node heading and its associated text. Programs for traversing the semantic net provide the outlines which through several options, give different perspectives of the hypertext to the MUCH user (see 'Traversal Options' window in figure 1). The author, date and/or author credit information can also be displayed across the outline on request. The system automatically creates a word index (Zeb, 1993) that consists of all the words and their respective occurrence in text blocks (Egan et al., 1989). The word index provides the basis for searching words throughout the document.

EFFICIENCY EFFECTS IN WRITING WITH GROUPWARE

Several groups (with overlapping membership) have used the MUCH system for the collaborative writing of a number of books for a period which spanned several months. In this paper, we present a survey among the authors of those books to explore the value of collaborative hypermedia in supporting efficient collaboration. We have pursued this study to investigate efficiency effects on five aspects of collaborative writing with

the MUCH system: (i) satisfaction with the group writing process; (ii) coordination of group writing; (iii) relation between breakdowns and quality of output; and (iv) relation between forms of collaboration and breakdowns. In the following subsections we describe the research issues related to the above aspects of efficiency in collaborative writing.

Satisfaction with the Group Writing Process

Research in user performance satisfaction suggests that technology does not have a significant effect on satisfaction (Olson et al., 1992). Instead of technology, characteristics of the group (e.g. communication and attitudes towards the task) are the best predictors of user performance satisfaction (Hiltz and Johnson, 1990). However, satisfaction has been used as a measure of fit between what people perceive as an ideal situation and what they perceive they are receiving. A bad fit indicates some unsatisfied needs (Hirschheim, 1985). These needs may differ when people use different technologies to accomplish their work. Our goal is to identify such needs by comparing satisfaction with four factors that characterise group work. These factors include communication thoroughness, equality of participation, perceived progress, and perceived agreement (Jarvenpaa et al., 1988). We investigate the effects of the above factors on satisfaction when collaboration is mediated through collaborative hypermedia and contrast them with findings in our earlier work (Michailidis et al., 1993) where collaboration has been mediated through conventional technologies.

Coordination of Group Writing

Coordination problems may reduce efficiency in group work. Because coordination is characterised by confusion, disagreement, and lack of understanding it is argued that it is an equivocal process. Previous research (Daft et al., 1987) has shown that rich media are more appropriate for handling equivocal situations. That is, media richness is positively related to the equivocality of the task. Given that coordination is defined in terms of its activities, it is assumed that media richness is positively related to each one of the components.

In our earlier research (Michailidis et al., 1993), we found that coordination activities are not only interdependent but they may also be positively associated to each other in the sense that effective employment of one component may imply effective employment of another. This perspective in coordination is more realistic than considering each coordination activity in isolation. Coordination activities are not only interdependent but also interleaved. Technological support for coordination should acknowledge such interdependencies and promote positive relations among the activities. The MUCH support for coordination was evaluated by identifying the positive correlations among the coordination activities that are supported by MUCH. The coordination activities taken into account include communication, awareness, perception, transparency, commitment management, and decision making. It has been argued that new technologies should not be viewed as substitutes for existing ones but rather as offering new ways for supporting coordination (Johnson, 1989). In our earlier work, we observed that the number of positive interdependencies supported by different technologies depends on the richness of the technology. Face-to-face is the richest and most efficient modality to coordinate human activities (Sproull and Kiesler, 1991). Since collaborative hypermedia is richer than conventional technologies we expected that collaborative hypermedia would support more positive interdependencies than conventional technologies do.

Breakdowns and Quality of Output

We consider five kinds of breakdowns that may cause inefficiency (Nylund, 1989) in the group writing process. We asked the subjects to report the frequency that they faced these breakdowns. *Conflict over resources* is considered as a breakdown in the writing process. There are three kinds of resources (Sharples et al., 1993) that collaborating authors may use. External resources may include books, notes, references, time, plans. Cognitive resources may include ideas, knowledge, goals. Textual resources may include the draft documents that the group has already authored. Lack of adequate communication and awareness may result in

people *duplicating the work* that has already been done. That incurs costs of resources such as effort and time. Lack of notification of activities performed by the partners may result in people *undoing* the work of others. *Role misallocation* is considered as another kind of breakdown. In any collaboration it is difficult to know in advance what roles the partners should assume. Determining the proper roles and assigning them to the appropriate agents is often a trial and error process. Negotiation about roles and re-allocation should be done as soon as role misallocation is detected. Finally, *deadlock* is another kind of breakdown that is taken into account. Collaborative writing activities are interdependent and often the output of one activity is required as input into another (e.g. writing the results section of a paper before starting the discussion section). Deadlock is the situation when partners are wasting time waiting for others to fulfil their delivery commitments. The occurrence of breakdowns in the collaborative writing process might have negative effects on gorup efficiency in terms of quality of output.

Forms of Collaboration

The subjects in our experiment reported the forms of collaboration they experienced when they used the MUCH system. We ask them to choose one or more forms that were appropriate from the following list (Stratton, 1989), (Sharples, 1993a) (see also figure 2):

- Horizontal Division Model: The aim of the model is the equitable division of work and responsibility. Effective use of this model implies reduced communication that may lead to improper cognitive orientation, incompatibility of individual contributions and thus inefficient collaboration.

- Turn-Taking Model: The model ensures that the final product is consistent and redundancy is eliminated. The collaborators are able to make contributions to the entire document. The turn-taking model facilitates effective collaboration but it leads to inefficiencies in terms of time and effort.

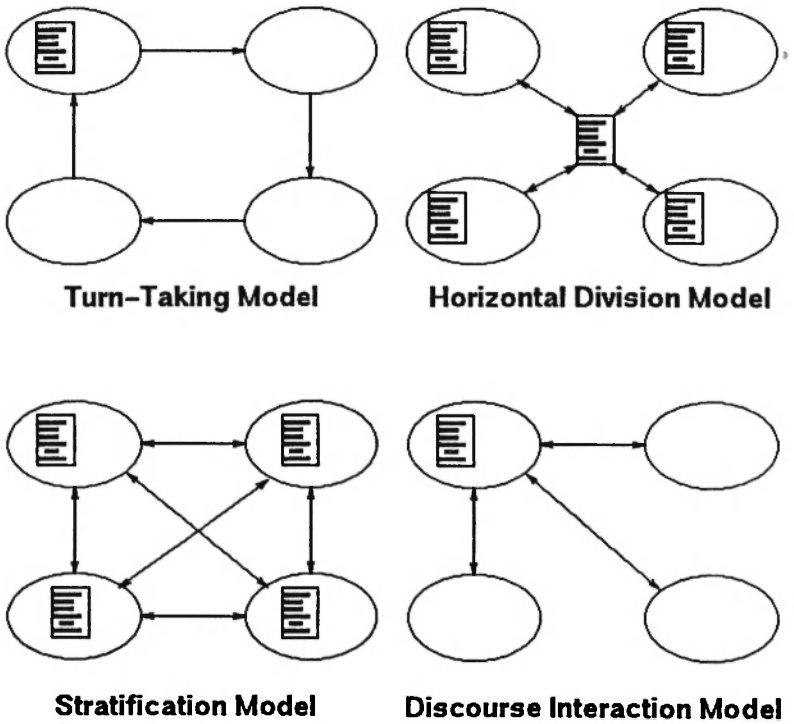

Fig. 2: Forms of Collaborative Writing (adapted and modified from Sharples, 1993a). The 'turn-taking' and 'horizontal division' forms of writing are asynchronous during their execution. The 'stratification' form can be both asynchronous and synchronous while communication in the 'discourse interaction' form is synchronous.

- Stratification Model: The value of collaboration is that it brings together people with complementary skills. These skills must be mapped into appropriate roles. A person can be particular good in certain roles. To build a successful team a balanced combination of roles is necessary. The aim of the stratification model is to achieve a balanced mapping of roles into tasks.

- Discourse Interaction Model (Coutoure and Rymer, 1991): Discourse interaction refers to the communication (spoken or written) relevant to the document creation process during the phases

of planning, drafting, and revising. This model of interaction between the writer and other(s) may be the most frequent form of collaborative writing.

- Any combination of the above.

We are interested in the range of forms that the MUCH users have employed and what form of collaboration is most frequently being followed. The forms of collaboration may affect the efficiency of collaborative writing (Stratton, 1989). Here we measure efficiency by the frequency of the occurrence of breakdowns described in the previous section, and we hypothesise that: the frequency of breakdowns varies according to the form of collaboration.

METHOD

A survey was designed to investigate the issues stated above and to test the hypotheses. A questionnaire was distributed to users of the MUCH system that have experienced collaborative writing using MUCH. The questionnaire was organised around five aspects of the writing process: (i) satisfaction with the group writing process; (ii) coordination of group writing with the MUCH system; (iii) relation between breakdowns and quality of output; and (iv) relation between form of collaboration and breakdowns. This section describes the method of the study in terms of subjects, measures, and procedure.

Subjects

Twelve subjects were selected from a computer science department. All subjects had used the MUCH system for writing books in groups with overlapping membership. Six of them were postgraduate students and the rest (six) were undergraduates. All subjects completed and returned the questionnaire. The subjects participated in the study voluntarily, no inducements were provided to obtain their cooperation.

Measures

A questionnaire was distributed to the subjects. All questions but one consisted of one or more statements to be ranked on seven-point scales (Likert Scales). One question was designed to measure user satisfaction with the group process. Four questions were designed to capture user evaluations of four aspects of group writing with MUCH: communication thoroughness, equality of participation, perceived progress, and perceived agreement. Five questions focussed on coordination activities such as awareness, perception, transparency, commitment management, and decision making. The breakdowns in the process were addressed by one question that consisted of five statements. In each statement the subjects were asked to report the frequency that they faced conflict over resources, duplication of work, undoing others' work, role misallocation, and deadlock. The subjects were also asked to indicate the form(s) of collaboration they have experienced.

Procedure

All the subjects were given the same instructions on how to complete the questionnaire. It was pointed out that there are no right or wrong answers and that the questionnaire is not a test. They were also notified that their responses would be kept confidential. The subjects were asked to answer the questions in a way that reflects their experiences using the MUCH system for group writing.

RESULTS

We present the results of the survey in the following subsections. In the first subsection the results related to satisfaction are presented. The second subsection covers the coordination part of the questionnaire. In the third subsection the results related to performance issues in group writing are presented. Finally, the fourth subsection summarises the results about issues concerning the form of collaboration.

Satisfaction with the Group Writing Process

The data collected from the satisfaction part of the questionnaire are summarised in table I. Respondents to the first question felt 'neither satisfied nor dissatisfied' with the collaboration. The subjects reported that collaboration was 'a fair amount' effective towards the stated goals. Effectiveness of communication was not rated highly. It received the lowest score as compared with the other factors. Respondents considered that effective communication was achieved to some extent. Both agreement and equity of participation received the highest score (mean = 4.5). Respondents reported that 'a great amount' of agreement was achieved amongst the group members towards the stated goals despite the variance observed in their responses. The rates varied from 'very little' to 'total agreement'. The subjects felt that they were 'often' free to communicate and contribute during the group writing task.

Table I. Summary of the results from the Satisfaction questionnaire.

Question	mean	sd	range	N
To what extent are you satisfied with the collaboration?	4.4	1.165	2-6	12
To what extent is the collaboration effective in terms of the progress towards the stated goals?	4.3	1.073	3-6	12
To what extent is effective communication achieved amongst the parties towards the stated goals?	3.7	1.497	2-6	12
To what extent is agreement achieved amongst the parties towards the stated goals?	4.5	1.446	2-7	12
How often do you feel free to communicate and contribute?	4.5	1.732	2-7	12

Correlation tests, using the Spearman's rank-difference correlation method, among the factors related to satisfaction indicate three positive

correlations statistically significant at $p<0.05$: (i) Participants who report that effective communication was achieved amongst the group members towards the stated goals also tend to report that they were satisfied with the collaboration; (ii) Participants who report that agreement was achieved amongst the group members towards the stated goals also tend to report that they were satisfied with collaboration; and (iii) Participants who report that agreement was achieved amongst the group members towards the stated goals also tend to report that effective communication was achieved amongst the group members towards the stated goals.

The results in our previous work on conventional technologies indicate only one correlation between satisfaction and communication thoroughness (see figure 3). The results in the present study indicate two positive correlations between satisfaction and progress to the goal and agreement.

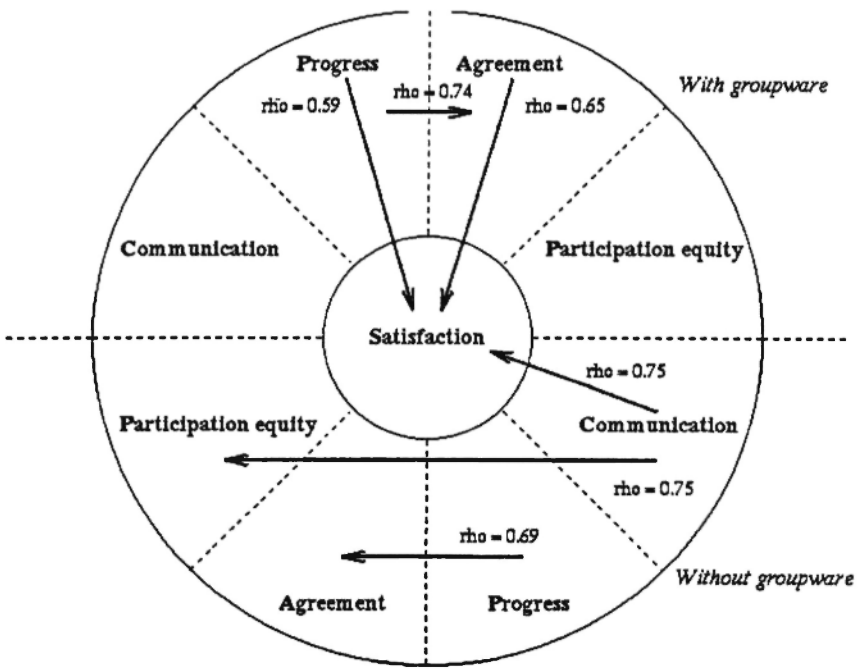

Fig. 3: Factors that may affect satisfaction with both groupware and conventional technologies.

Coordination of Group Writing

We asked the MUCH users to judge the system against six coordination activities (communication, awareness, perception, transparency, commitment management, and decision-making). The results are summarised in table II.

Table II. Summary of the results for coordination.

Coordination Activities	mean	sd	range	N
Communication	3.667	1.497	2-6	12
Awareness	3.500	1.508	1-6	12
Perception	4.417	1.443	2-6	12
Transparency	5.417	0.900	4-7	12
Commitment management	3.917	1.676	2-7	12
Decision making	4.333	1.435	2-7	12

The MUCH system received the highest score for Transparency. Participants consider that they have been to 'a great amount' able to access information produced by others. Their responses varied from 'a fair amount' (two responses) to 'totally' (one response) while most (five) participants responded 'almost totally'. The standard deviation was also the lowest for Transparency. This indicates that there is agreement among the participants in their judgements. Participants rated less favourably Perception, Decision-making, and Commitment Management. The subjects responded that they have to 'a fair amount' maintained an accurate view of the other members, participated and influenced decisions, and that the other members kept their delivery commitments. The system received the lowest scores under awareness and communication. Although awareness is considered to be 'somewhat supported', this result is biased by the fact that participants had often the chance to meet face-to-face in both working areas and in common rooms. So they maintained a background or passive awareness that is not mediated by the system. People who did not have the chance to meet regularly face-to-face rated awareness unfavourably. Providing computer-based mechanisms for the first category of users may not be appropriate since that could interfere with their normal working style. Such mechanisms could be beneficial to the second category of users.

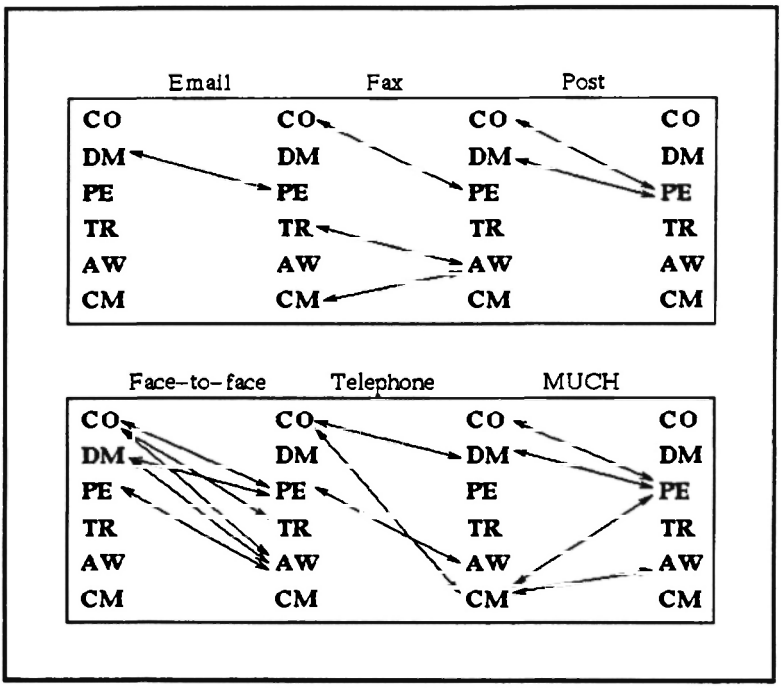

Fig. 4: Comparison of the positive coordination interdependencies supported by email, fax, post, face-to-face, telephone, and MUCH. CO: communication; DM: decision-making; PE: perception; TR: transparency; AW: awareness; and CM: commitment management.

We performed correlation tests to identify the positive interdependencies among coordination activities. We display our results of statistically significant interdependencies at the $p<0.05$ level in figure 4.

According to the hierarchy of media richness (Daft et al., 1987), the technologies that we have examined in our previous and the present study can be ranked as follows in terms of increasing richness: post (1), fax (2), email (3), telephone (4), collaborative hypermedia (5), face-to-face (6). The numbers in the brackets represent the number of the positive correlations among coordination activities that each technology supports. Judging the richness of technology is based on a combination of four criteria: the extent

that the technology enables (i) instant feedback, (ii) multiple cues to be included in the exchanged messages, (iii) language variety in the sense that a wide range of meaning can be easily conveyed, and (iv) personal focus in the sense that emotions and feelings are properly conveyed (Daft et al., 1987). Collaborative hypermedia is considered as richer technology than telephone in this experiment, despite the fact that telephone satisfies the four criteria to a greater extent that collaborative hypermedia. In the present study the subjects have used face-to-face communication in parallel with their work on the MUCH system and their responses may have been biased. That technology richness is analogous to the number of positive interdependencies supported by technology is true in an environment where subjects can easily have face-to-face communication.

Breakdowns and Quality of Output

Participants were asked to judge the quality of the final document. The subjects considered that the documents they produced were 'neither weak nor strong'. The subjects were also asked to report the frequency of the breakdowns they have encountered during the group writing. Their responses are summarised in table III.

Table III. Summary of results on breakdowns.

Breakdowns	**mean**	**sd**	**range**	**N**
Conflict	1.818	0.751	1-3	11
Duplication	2.545	0.934	1-4	11
Undoing	2.182	1.382	1-5	11
Role misallocation	2.545	1.508	1-6	11
Deadlock	2.909	1.640	1-5	11

The participants reported that they have experienced conflict over resources 'once in a while'. The small range and the low standard deviation imply that there was agreement among the respondents. Respondents seem to agree that they have 'sometimes' faced duplication of work. They also reported that 'once in a while' someone undid work of his/her partners. However, responses varied from 'never' to 'often'. Participants felt that 'sometimes' role misallocation occurred. However, the high standard

deviation and the wide range of ratings indicate that there is disagreement among the participants. The differences in the results may be explained by the group autonomy (Gere, 1987). People who worked in semi-autonomous groups faced less frequently role misallocation. On the other hand the persons who responded 'often'; or 'constantly' worked in non-autonomous groups where role allocation is not negotiable and thus have limited influence on it. Deadlock received the highest score. People felt that they 'sometimes' wasted time waiting for their partners to finish their work before they proceed further. Although the mean values of the responses did not vary greatly the same does not hold true for the standard deviations. A within-subjects ANOVA test was performed to test whether differences in the mean values were significant. The results ($F(4,40) = 1.629$, significant at the 0.1850 level) suggest that there are no breakdowns that occur more frequently than others.

Correlation tests among the breakdowns and quality were performed to identify relations among them. It was expected that negative correlations should exist, if breakdowns are closely related to quality. The results indicate only one negative correlation ($rho = -0.590$, $N=11$) between undoing others' work and the quality of the final document statistically significant at the $p<0.1$ level. That is, when people report that they have often faced situations where someone undid his/her partners' work, they also tend to report that the final document is weak in terms of quality. One reason for this result may be that the breakdowns, that have been taken into consideration in this study, do not adequately capture the factors that contribute to decrease of quality in collaborative writing. For an elaborated classification of breakdowns see (Urquijo et al., 1993).

Forms of Collaboration and Breakdowns

A collaborative writing system should be flexible enough to accommodate the variety of writing styles that different groups may prefer. To judge the flexibility of the MUCH system the subjects were asked to report the form of collaboration they had experienced. Each subject could

select more than one of the forms stated in section 'Forms of Collaboration'. The responses were quite diverse and covered almost all the forms.

Following the new classification, the horizontal division (selected eight times) and the stratification (selected seven times) forms emerged as the most popular among the MUCH users. The turn-taking form was selected once, while none of the subjects experienced the interactive form. It has been argued that the form of collaboration may affect efficiency (Stratton, 1989). To investigate this hypothesis, the breakdowns reported by the subjects previously were examined.

People who employed a horizontal-division form of collaboration reported that they faced duplication of work more often than any of the other breakdowns. They were involved in such a situation 'sometimes' while they responded that they faced 'once in a while' conflict over resources, undoing others' work, role misallocation, and deadlock. The reported frequency distributions for each kind of breakdown are displayed in figure 5.

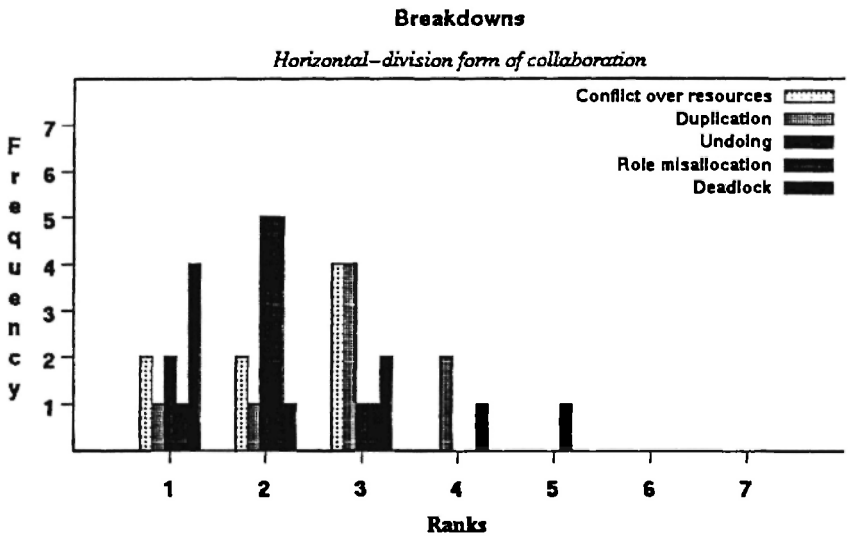

Fig. 5: Histogram of breakdowns in horizontal-division form of collaboration.

Conflict over resources, undoing others' work, and wasting time waiting for someone to finish his/her work received the lowest scores mainly because of the limited interaction among collaborators that this model of work solicits. Duplication of work occurs quite often because the partners are not aware of their partners' activities. They can only detect it at the end of the work when they merge individual contributions. Usually roles in this model are defined at the beginning and are not re-assumed in the course of the work. It may take some time to discover that the roles have not been assigned properly and it may require major effort and reorganisation to perform role re-allocation and negotiation.

In the stratification form deadlock was the breakdown that occurred more often than the other types. Responses suggest that the participants were waiting for someone in the group to finish his/her work 'fairly many times'. They have also reported that they faced duplication of work and role misallocation 'sometimes'. Conflict over resources and undoing others' work received the lowest scores. Participants thought that they faced such situations 'once in a while'. There is a split among the collaborators' opinions to the extent that role misallocation occurred (see figure 6).

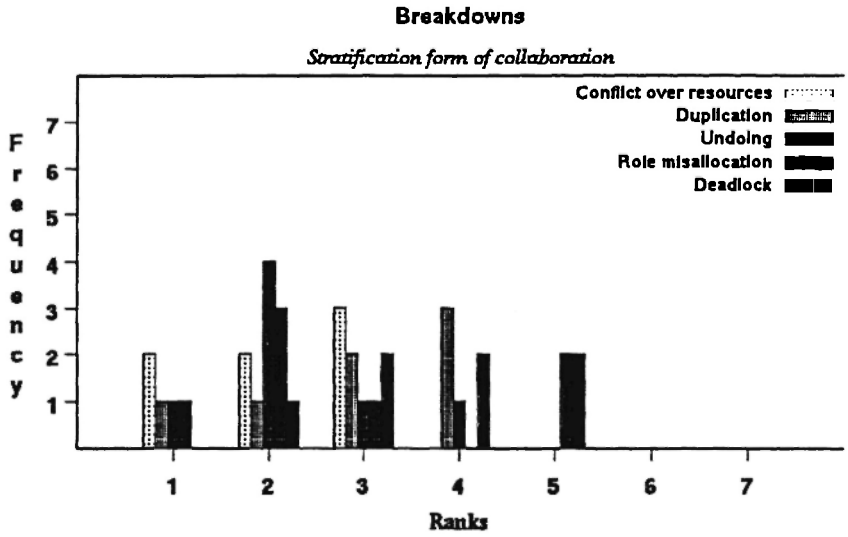

Fig. 6: Histogram of breakdowns in stratification form of collaboration.

We observed, by comparing the results in figures 5 and 6, that the hypothesis that there are differences in the frequency of breakdowns across different forms of collaboration may be true only for deadlock breakdowns. The results seem to suggest that the occurrence of the other types of breakdowns was similar in both 'horizontal-division' and 'stratification' forms of collaboration.

DISCUSSION

In this study we investigated the effects of collaborative hypermedia on the efficiency of collaborative writing in an academic setting. In particular, we have observed people writing documents collaboratively using the MUCH system. The people who used the MUCH system for collaborative writing over a substantial period of time were surveyed. Despite the limited number of subjects (twelve), they all had substantial experience in using the system for real-life tasks. That implies that the subjects in the MUCH study were familiar enough with the system. We consider that their familiarity should add to the validity of their responses (Eveland and Bikson, 1988) which may otherwise be reduced by the small sample size.

When satisfaction is used as a measure of efficiency, the study suggests that two factors may have an effect on efficiency, progress towards the goal and agreement. Breakdowns that inhibit the progress of the work may result in reduced efficiency. Similarly, when people have problems in reaching agreement towards the goals then efficiency is reduced. The comparison of these results with the results on satisfaction reported in our previous research confirms the hypothesis that efficiency is affected by different factors depending on the technology being used. When conventional technology is used for gorup work then breakdowns in communication thoroughness have negative effects on efficiency.

One reason is that conventional technology serves communication needs during the collaboration. Similarly, collaborative hypermedia seem to

affect the way people sense progress of the work and the way they develop common cognitive orientation. Providing facilities that would inform collaborators on the progress of the work and also help them develop cognitive orientation is expected to improve efficiency of work. The result that the communication thoroughness does not relate to efficiency when people use collaborative hypermedia can be explained by the fact that the subjects relied more on conventional technologies for communication rather than on the MUCH system.

The results on the coordination part of the questionnaire showed that the choice of technology for coordinating the work depends on the richness of the technology. The more equivocal the coordination task is the richer the technology that the people will use. However, this may be true only for highly rich technologies and not for text-based technologies. But the question that arises here is for which coordination activity is the collaborative hypermedia technology most appropriate? The results showed that collaborative hypermedia supports transparency better than any other coordination activity. The reason is that the particular collaborative hypermedia technology (MUCH system) used in this study has been designed to support both the hierarchical structuring of information and easy access to it.

In this paper in addition to the above dimensions of efficiency that have been raised in the literature, explicit investigation of breakdowns in the collaborative writing process has been pursued. The effect of the occurrence of breakdowns on other aspects of gorup performance showed that only one kind of breakdown (undoing others' work) might have significant negative effects on quality of the final document. That implies that different breakdowns in the writing process may affect its outcomes to a different extent. Moreover, our findings also suggest that the form of collaboration may not affect the occurrence of breakdowns except for deadlock which is more likely to occur in the stratification form of group writing.

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