Types of Knowledge Exchange During Team Interactions: A Software Engineering Study

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Abstract—**A field study performed in a professional software development environment shows that the interactions between collocated teammates have various purposes. This paper presents a comprehensive study of ad hoc communications on collocated team based on video recording of professional developers within a large organization. It is found that there are four purposes for ad hoc face-to-face communications; collaboration, cooperation, coordination and socialisation. To be able to use collective tools in distributed or virtual team environments we must be able to support at some extent the purposes of ad hoc communications that occur naturally in social presence. The main finding of this field study is that collective tools need to satisfy two different purposes. A cooperative system is needed to share the know-how needed to build the product and a collaborative system is needed to share the knowledge needed to understand the functionalities to be implemented.**

Keywords - face-to-face interactions; teamwork; field study; cooperation; collaboration

I. INTRODUCTION

Cooperative system is a general term to describe tools design to support collective activity. To better understand the needs for collective systems we studied team activity in a collocated environment. Although teams are common structures in today's workplace, the use of collective systems designed to support team activities is still an ongoing challenge [1].

Physical collocation mostly refers to a team room. The team rooms support social presence by enabling interactive continuous communications. Face-to-Face communication (FtF) is the major feature of collocated teams [2]. To be able to use collective tools in distributed or virtual teams, we must be able to support at some extent the purposes of ad hoc communications that occur naturally in social presence. The ultimate purposes of ad hoc interactions within co-located team are to exchange information and share or synchronize knowledge and mental model.

FtF communications can occur in two different ways within collocated teams. One way is planned FtF communications, which occur during scheduled meetings [3] [4], another way is ad hoc FtF communications, which occur spontaneously when teammates are working on their tasks within the collocated team environment. There is a large variety of cooperative systems to be used in scheduled or planned activities. This paper reports on a field study designed to identify the type of collective systems most likely needed to support collocated ad hoc interactions occurring during unscheduled activities. For example, when software developers are working solo on their assigned tasks.

FtF communications outside the meeting rooms occurred spontaneously without scheduling and with unknown duration. They are usually very brief but sometimes they can last very long. These FtF interactions are ad hoc and opportunistic because they are triggered on a just in time basis and their content is unpredictable. The initiator takes the opportunity to interact with a targeted teammate in hoping that this communication will provide him with relevant information to help him pursue his task or else. Spontaneous ad hoc FtF communication is one of the unique features of collocated team.

These ad hoc FtF communications are initiated during "quiet time", which is when collocated teammates are working by themselves while sitting at their workplace. Ad hoc FtF communications require immediate attention and constitute for the receiver an interruption of work activity. Many studies have shown the importance of ad hoc communications in collocated team. This paper presents the analysis of ad hoc communications that occur during this quiet time and which constitute interruptions for the responders. One of the purposes is to find the kind of knowledge that is required by the responders.

In order to achieve a better understanding of *ad hoc* FtF communication within a software development team, we go further than previous studies by analyzing the inherent patterns and content of ad hoc communications. Such an understanding will provide clues to improving the environment for collocated software teams. Moreover, while studies have shown that distance raises barriers to informal communications, resulting in a number of coordination problems [5], we believe it is reasonable to expect that a better understanding of these informal communications will pave the way to further improvements of collective tools,

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which are likely to be more appropriate to the needs of the users [6].

This paper reports on a field study based on video recording and performed in a professional software development environment, which last for few months. The purpose is to understand these natural phenomena found in collocated team. The results of this study are useful to the participants to help them understand the purposes of this activity and improve its used. Researchers interested in knowledge sharing activities are likely to find some of the reasons and the content of such ad hoc communications, which may help them to propose adapted and optimized practices to support the ad hoc communication purposes.

Section 2 presents the methodology used to capture the information from teammate interactions. Section 3 presents the physical characteristics of the interactions. Section 4 presents the dynamic of ad hoc FtF communications. Section 5 is a discussion on the validity of this data and the usefulness for the participant, and the managers.

II. METHODOLOGY

The research was conducted in the form of a field study in an professional software engineering setting, and relied mostly on participant observations, as described by Jorgensen [7] and Babbie [8]. The goal of this field study is to observe a collocated team, where developers are free to interact with one another. Our purpose is to measure *ad hoc* FtF communications occurring in a real professional environment.

The observed team was composed of 1 project manager and 3 software developers within a team of 12 developers, with varying levels of schooling (from Bachelor to Ph.D. degrees in computer sciences and engineering), and individual experience ranging from 9 months to 5 years of service in the company.

The total observation period lasted two months. For this study, we selected 12 regular half-day sessions from the 23 recorded. These sessions are distributed over the two months of the recording time and account for 35 hours of video recording, resulting in 404 vocal communications.

A half-day session lasts 2 to 3 consecutive hours. A regular session is defined as a session where all teammates are present and where there are no special events, such as meetings, visitors, etc., which could disturb the usual *ad hoc* FtF communications occurring during normal working activities. The researchers received human-subject approval from the University and the participating Company.

In this study, participants spent almost 30% of their working time in *ad hoc FtF* communications. Most FtF *ad hoc* communications (84%) involved only two participants, which indicates that an *ad hoc* communication is directed to a particular teammate by its initiator.

III. PHYSICAL CHARACTERISTICS OF AD HOC FTF COMMUNICATIONS.

This section describes how the ad hoc communications are distributed among the various regular working sessions with respect to their purposes. After many analysis iterations, we characterize the ad hoc FtF communications according to four purposes, which are socialization, coordination, cooperation and collaboration.

FtF socialization interaction supports the process by which individuals acquire the knowledge, social skills and value to conform to the norms and roles required for integration into the group.

FtF coordination interaction, which is defined as managing *'dependencies between activities', is* done mostly in *s*cheduled meetings where participants have common objectives on which the exchanges are based [9]. Coordination is characterized by formal relationships and understanding of compatible missions.

FtF cooperation interaction occurs when individuals reach some mutual agreement, but their works together do not progress beyond this level. In cooperation, activities are mutually agreeable but not necessarily for mutual benefit. Cooperation is characterized by informal relationships that exist without a commonly defined mission, structure or effort. Information is shared as needed. Typical cooperation activities are for example, giving a help with a debugging task.

FtF collaboration interaction is a recursive process where two or more people work together in an intersection of common goals that is creative in nature—by sharing knowledge, learning and building consensus. Collaboration is usually on demand from at least two team members that want to work together on a specific task. Examples of collaboration are some forms of pair-programming. All the collaborators have a genuine interest in the same activity [10].

Figure 1 shows the cumulative duration in minutes for each ad hoc FtF communication purpose and within each session. For example, Session 1 (Column 1) sums up to more than 40 minutes of ad hoc collaboration, 80 minutes of ad hoc cooperation, few minutes of ad hoc coordination and almost 20 minutes of ad hoc socialization. We observed that the four purposes occurred in all of the observed sessions but Session 6 which had few ad hoc FtF communications. Figure 1 shows also that the total time spends in each ad hoc FtF communication is largely variable amongst the various sessions. It ranges from 20 minutes for Session 11 to 2 hours and haft for Session 8. Cooperation and collaborations are the main purposes of FtF ad hoc communications. This figure shows that coordination and socialisation are not the major reasons for ad hoc communications during working sessions.

Figure 2 shows that almost a three-quarter of these interactions are for collaboration and cooperation purposes, each with a frequency occurrence of 37% and the remaining are for coordination and socialization. This pie

chart illustrates that from all the ad hoc FtF communications observed over the recording period only 10% are for coordination purposes. We recall that this is a kind of micro-coordination that occurred during ad hoc interactions only. This type of coordination does not take into account the formal coordination meetings that occurred regularly during the life-cycle of a project.

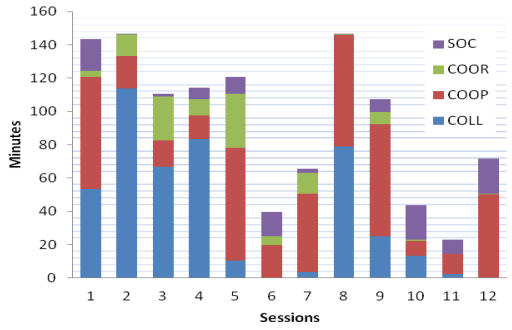

Figure 1. Cumulative duration in minutes for each of the FtF communications purposes within a recorded working session.

This first part of the analysis tells us that ad hoc FtF communications occurred mostly to satisfy two needs where one need is related to the tasks (collaboration and cooperation) and where the other need is related to the ancillary activities of the task, coordination and socialization, which are less frequent and much shorter. The first finding is that ad hoc FtF communications are mostly initiated to help participants in accomplishing their tasks through collaboration or cooperation.

According to this study, the coordination activities that occur on an ad hoc basis during the quiet time are mostly micro-coordination activities, which are related to team awareness. For example, a team member will state that his module is now ready for release or that he will test another module in the afternoon. There is little need for collective systems that will support micro-coordination activities, since it concerns less than 10% of the ad hoc interactions.

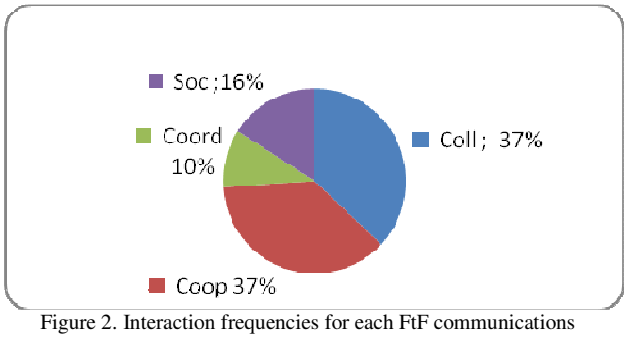

Figure 2. Interaction frequencies for each FtF communications purposes.

However, it might be useful to have a dedicated and easy to use tool, which may keep track of all these micro-coordination activities, to be able to trace them back in case of problems or to justify delays in the development plan.

IV. INITIATORS OF FTF AD HOC COMMUNICATIONS

Who are the initiators of ad hoc FtF communications? Is it everyone occasionally or is it few individuals that need to interact more often than others?

Since ad hoc collaboration and cooperation are the major cause for ad hoc FtF communications we make a closer analysis of their initiators. Figure 3 shows the relative frequencies of ad hoc collaboration initiators. Almost everyone on the team (9 out of 12 people) initiate, at some times during our recording period, an ad hoc collaboration. However, one individual (MS3) initiates more that the third of all the ad hoc collaboration. Only two other participants initiate more than 10 % of the ad hoc collaboration. It has been found that MS3 was involved in the modification of a module that has been developed some times ago by other team members and they all want this shared module to be well-maintained, which resulted in close collaboration on this task. There are six (6) other participants that share 39% of the collaboration initiatives.

In the light of this data, we can speculate that for certain tasks ad hoc FtF collaboration can be supported by collaborative tools that are likely to facilitate knowledge transfer and reduce interruptions.

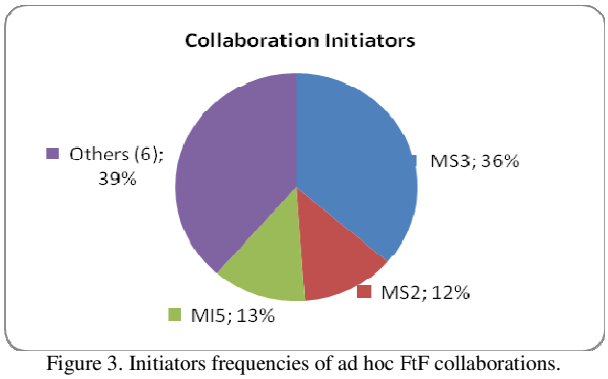

Figure 3. Initiators frequencies of ad hoc FtF collaborations.

Figure 4 shows the relative frequency of ad hoc FtF cooperation. It is observed that everyone (14 people) initiates ad hoc cooperation during the observation period. Actually, we had 2 people initiating ad hoc cooperation that was coming from outside this team of twelve (12). The leading initiator is MS1 with almost a quarter of the ad hoc cooperation initiations. MS1 is the last recruit on the team and this data shows clearly his needs for just-in-time help form others to efficiently do his task. Ad hoc cooperation from others (eleven individuals) account for 46% of the number of cooperation initiations.

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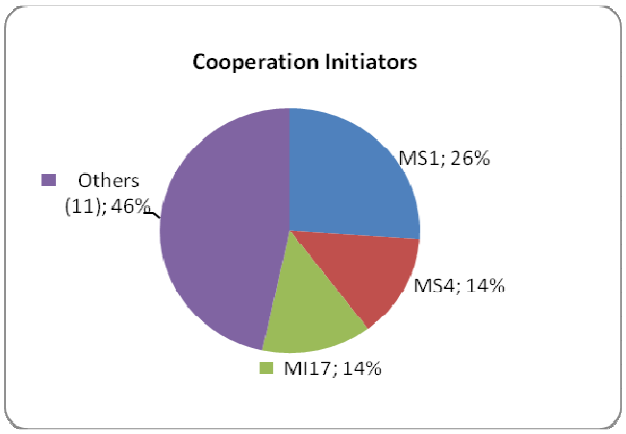

Figure 4. Initiators frequencies of Ftf ad hoc cooperation.

Closer analysis of ad hoc cooperation data suggests ways to reduce cooperation interruption. One way is to provide a cooperative system tools that will provide answers and record questions from the teammates. A dedicated FAQ (Frequently Asked Question) system could be a good example of such a tool.

V. DISCUSSION

This field study analysis shed light on the various needs for collective systems. Ad hoc FtF communications involving coordination, cooperation and collaboration are key components to maintain high level of awareness within a collocated team [11][12]. Dourish and Bly [13] define awareness to be "an understanding of the activities of others, which provides a context for your own activity." Maintaining awareness is the process by which individuals working with others transmit and acquire information, consciously or unconsciously, about their work efforts and how these efforts fit in with the on-going work of others. Our data shows that Ad hoc FtF communications contribute to the team awareness since they are not limited to few individuals but involve almost everyone within the team.

Ad hoc FtF collaboration can occur at any time during the working session, and developers address this need at the opportune time, that is, when an answer is required to complete the task with someone else sharing interest and benefit in the task. Ad hoc FtF cooperation presents the same intrinsic motivation. It occurs when questions come up about what to do or about how to do it. Developers seek the help of colleagues to obtain missing information, to ask for advice, or for guidance to pursue their tasks. Collective systems can help increase the efficiency of these interactions by providing appropriate coordination, cooperative or collaborative system tools.

Ad hoc FtF socialization is the less important purpose for ad hoc communications during normal working hours. This need for socialisation is probably well satisfied before work started, during breaks or lunch times. These periods have not been recorded during our study. To facilitate socialisation, some organisation may use collective games like ESP Game [14] applied to their own products.

Ad hoc FtF coordination occurs when there is a need to synchronize the activities of teammates on the tasks to tackle, and to plan for further activities. Coordination is not the predominant type of *ad hoc* communication in terms of frequency and time spent. Nevertheless, coordination activities are vital for maintaining synchronization of team activities, as well as for avoiding deadlocks or confusion in task organization. Coordination interactions are probably the easiest activities to support through electronic means for distributed teams. This activity is usually under the responsibility of the team leader and the agenda is well defined. Coordination is efficiently achieved today with shared calendar. However, micro-coordination in distributed teams may need some kind of support tools to maintain the team awareness on task progress.

Based on the patterns described above, *ad hoc* FtF communication seem to originate noticeably from a natural, unconscious, and *ad hoc* opportunistic process that takes place during software development activities. As discussed by Robillard [15], an *opportunistic* process, is defined by an incremental process in which knowledge is gathered as opportunities present themselves, and depends on the cognitive availability of the necessary information. On the opposite, a *systematic* process occurs when all the knowledge required to complete a task is available so that a well-structured plan can be followed.

An opportunistic process has been observed, in the software development settings studied, in the form of the *ad hoc* FtF communication of teammates to gather, in a *just-in-time* manner, the information they need to accomplish the task at hand. Collective tools may help this process by recording the information that is shared and more importantly by providing a repository where the most needed information can be found. Such collective tools are likely to reduce the interruptions initiated by FtF interactions.

A. *Task-Centric Content of Ad hoc Communications*

Studies on the topic (what) of *ad hoc* FtF communications have uncovered two contrasting content topics. On the one hand, development environment was the topic in more than 40% of the total *ad hoc* FtF communications, which relate to general *know-how* matters. Artifacts prescribed by software processes are based on knowledge related to the software to be built. These artefacts do not address *know-how* needed to build these software components. We believe that identifying and recording the recurring ad hoc FtF communications regarding these *know-how* interactions constitute a unique opportunity for optimizing cooperation interactions. For example, setting up a web based FAQ for development environment questions.

On the other hand, the results reveal that more than a third (35%) of the FtF communications concerned product

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related topics, which are related to the software to be built. Studies on the information needs of software developers, identified the search for a design and code rationale as an important source of *ad hoc* interruptions [10]. As pointed out by previous authors, the degree to which diverse contents of the software to be built are discussed, raises questions about the adequacy and accuracy of the artifacts prescribed by software processes [16]. A Wiki structure based on concerns may make an efficient collaboration tool. Developers, who are adding or retrieving information, are sharing the same objective, which is collaborating to improve the shared understanding of the product.

Cooperation could also be efficiently computer mediated for well-defined tasks. A typical example of cooperation is when an expert helps a novice to accomplish a specific task.

Collaboration, which is based on shared goals and trust, is more difficult to computer mediate because it required some level of awareness and socialization. Efficient collaboration is based on trusted relationships, mutual respect, and on the expected capacity of the collaborators to contribute at reaching the goal. Ad hoc FtF communications are, still today, very difficult to support in distributed teams [17].

B. Ethical Issues

We considered the ethical implications of this research early on, at the planning stage, and ensured that all subjects and the hosting organization understood their rights and responsibilities before they agreed to participate [18]. All the individuals involved in our study were duly informed that their work sessions would be recorded, as well as of the nature of the study. They all signed the letter of agreement required for certification. Ethical issues were handled according to the established Canadian policies for research involving human subjects [19].

C. Scientific Value

The scientific value of this research has two components: the non-invasive study of the natural human communication in software development and the validity of the field study results. The social and collocated team aspects of software engineering constitute the major issues of this study. We believe that understanding these aspects is crucial to understanding how practices could be computer supported by appropriate tools. Global software development involves a de-located team, where verbal and FtF interactions via electronic means continue to occur. This study shows some of the parameters involved in the usual *ad hoc FtF* communications among collocated team members. These results can serve as a basis for a more in-depth study of the impacts of *ad hoc* interactions via electronic channels.

The validity of the observed results mostly relies on the fact that they faithfully and reliably represent reality. This study was not an experiment, where the various parameters could be controlled. This paper reports observations performed in a real professional environment in the course of carrying on day-to-day business. The salient outcomes of these observations, regardless of the specific setup of the organization, are a better understanding of the *raison d'être* of *ad hoc* FtF communications and how they take place and how they can be computer supported.

D. Study Limitations

One limitation of this study is inherent to most field study. The conclusions ensuing from this specific research cannot be generalized to all software development settings. However, owing to the characteristics that the featured settings have in common with the software development environments that can be encountered in the industry, we can assume that the outcomes of this study can be applied to a broader set of organizations.

Moreover, the *ad hoc* FtF communications observed in the framework of this research have been inducted in a maintenance context. Since maintenance contexts, where existing software is enhanced, predominate in software engineering settings, it is reasonable to assume that the results of this research are applicable to a broad set of contexts.

Finally, the method of video recording chosen for collecting the data poses a number of challenges, such as the background noise emerging from an open work space hosting hundreds of developers. It has several advantages, however: it can be reviewed as often as needed, and it is considered by participants to be less intrusive than having an observer take notes on their activities.

E. Validity Concerns

A coding scheme has been defined for the four purposes of *ad hoc* communication. Three coding agreement phases (inter-, intra- and extra-coder) have been applied to validate the data from the subjective coding. The first phase involved an intra-coder agreement, where a number of encoded data sequences were re-encoded a month later by the same coder. The second phase involved an inter-coder agreement, where the same coding operation was performed, by another coder who was able to understand the context and the jargon employed by both the participants and the primary coder. Finally, the third phase involved an extra-coder, were the same operation was performed by an experienced coder who was not familiar with the team work. An index proposed by Perreault and Leigh [20] was used to measure the subjectivity of the coding.

The indices obtained through the intra coder agreement were very high (.98). Inter-coder agreement show an agreement between the two coders with a value of 0.89, which is above the 0.7 limit, enabling us to deduce a strong agreement. The indices obtained with the exta-coder (.72) shows that the validity is still acceptable event when the coding is done by someone who is not familiar with the collocated team environment and its work.

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VI. CONCLUSION AND FUTURE WORK

Through this research, it has been possible to shed some light on the main aspects of *ad hoc* FtF communications in terms of the communication mechanisms in which they are conducted, but more importantly their purposes and the content exchanged during those activities. This better understanding has revealed the opportunistic nature of ad *hoc* FtF communication, which constitutes the cornerstone for further theories and research about the phenomenon. It also paves the way for the introduction of improved practices based on collective systems to better support the various purposes of ad hoc communications, in collocated as well as de-located contexts. Further research will also be required to test the efficiency of such supporting tools in collocated as well as in de-located environments.

The main finding of this field study is that collective tools need to satisfy to different purposes.

- A cooperative system is needed for the sharing of the know-how needed to build the product
- A collaborative system is needed for the sharing of knowledge needed to understand the product functionalities.

The structures of these two systems are different. A cooperative system could be structured like a FAQ where the experts fill out the answers. A collaborative system could be structured like a Wiki where collaborating teammates are working together to fill out the information required by the shared tasks.

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