The Object-Oriented Team: Lessons for Virtual Teams from Global Software Development

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Abstract

We investigated coordination and communication processes in global virtual software development teams in three Indian multinational technology firms. While some of the teams in our study experienced many of the same things observed in prior research, some operated in strikingly different ways, so different, in fact, that they led us to propose a new type of organization for global virtual teams: the object-oriented team. In contrast to the traditional virtual team approach which strives to tightly couple team members through information rich media such as face-to-face and telephone communication, the object-oriented team strives to decouple team members through the use of well defined processes and semantically rich media that clarify, extend and constrain meaning. The set of principles embodied in the object-oriented team we believe may be applicable to many types of virtual teams, especially larger teams facing complex problems.

1. Introduction

Global virtual teams are teams whose members share a common purpose and are located in at least two different countries [13, 16]. While team members can choose to travel to meet together face-to-face much routine team communication is conducted remotely [21]. Global virtual teams are becoming more common as companies begin to compete globally [16].

Managing team processes and performing work in global virtual teams can be challenging. There are a myriad of different collaboration technologies that can be used by virtual teams, from Internet-based audio and video, to synchronous and asynchronous computer mediated communication (CMC) systems (e.g., e-mail, Notes), as well as traditional video and telephone conferencing. Understanding how and when to use which tool and media for what activities is a major challenge facing global virtual teams.

In this paper, we investigate global virtual teams in three Indian multinational technology firms. We focus on one type of global virtual team, global software development teams, to understand how they communicate and coordinate their activities during their projects. When we began this project, we anticipated affirming -- with some minor differences -- the lessons drawn in recent research on other types of virtual teams. While some of the teams in our study did experience many of the same things observed in prior research, some operated in strikingly different ways, so different, in fact, that they led us to propose a new type of organization for global virtual teams: the object-oriented team. We begin with an overview of prior research, present our methods, explain the results, and then in the discussion section draw together the findings to present the object-oriented team model and contrast it with the current paradigm for "traditional" virtual teams.

2. Prior Research and Theory

The use of global software development teams has rapidly increased over the last decade [3]. About 40% of the Fortune 500 now use global software development teams or outsource development to firms that use them [10]. The reasons for this are compelling: there is a large, as yet, untapped number of qualified programmers overseas (compared to the current shortage in the United States) and salaries overseas are typically lower than those in the United States [3].

The major challenge faced by global software development teams -- and most other types of virtual teams as well -- lies in communicating among team members and coordinating their efforts so that the team smoothly accomplishes its goals [3]. In traditional non-virtual teams, most communication and coordination is done in face-to-face meetings, with most project work accomplished outside of meetings [17]. Global software development teams generally do not have the luxury of using frequent face-to-face meetings to coordinate their activities. Instead, much work and the coordination of the

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teams' activities must occur through other means.

The nature of the project work changes as the project moves through the system development life cycle (SDLC). The SDLC used by the firms in this study had five major phases: planning (the development of a project plan), requirements analysis (capture and organization of system requirements, usually in the form of textual documents and use case diagrams), design (UML or DFD/ERD diagramming, and interface design), implementation (writing program code, unit testing, and acceptance testing), and deployment (installation). In the first two phases, planning and requirements analysis, there is much coordination and work beyond the bounds of the team itself, between teams and managers and users in the client firm. In the middle two phases, design and implementation, this extra-team coordination and work is reduced -- but still present. In the final phase, extra-team coordination and work again increases.

In this paper, we focus primarily on the coordination and work processes inside the teams, although we do discuss coordination and work between the team and the other individuals outside the team. Our focus inside the teams is because the teams have the greatest ability to control and manage their own coordination and work process; outside the teams, coordination and work processes are primarily driven by the client firms, each of which have their own approach to these activities.

Several popular press books [e.g., 9, 11, 14] and a few academic studies have examined virtual teams, as well as global virtual teams and global software development virtual teams [e.g., 3, 13, 15, 16, 21]. While each team and organization is different, some general patterns have emerged in the way in which virtual teams operate.

Teams work together using a variety of media, ranging from traditional face-to-face meetings, telephone calls, fax, video conferencing, e-mail, and groupware, depending upon what tools are available. For example, some teams use face-to-face meetings, while other teams are unable or unwilling to spend the time and cost to meet face-to-face. Some teams primarily use "old media" (e.g., face-to-face, telephone) while others primarily use "new media" (e.g., e-mail, groupware) but most teams use a mix of both. But even in teams that use new media, the old media still play a key role [e.g., see 15, 16].

One of the dominant findings of Maznevski and Chudoba [16] was the need for deep temporal rhythms of interaction used to coordinate activities and make important decisions. These "[face-to-face] coordination meetings served as a heartbeat, rhythmically pumping new life into the team's processes" [16, p. 486]. The teams used face-to-face meetings to drive the projects on which they worked, with the time between meetings used to conduct the work agreed upon at the meetings.

The general pattern for virtual teams in prior research is one in which information rich media such as face-to-face or telephone conversations [6] are used to draw team members together to discuss, plan, structure, and -- sometimes -- execute the work that is to be performed. The goal is to connect, couple, and integrate team members as closely as possible so that they can communicate more effectively. The rationale behind this integration of team members was put forward quite eloquently by Daft and Lengel's [6] media richness theory (MRT). MRT argued that managers could improve performance by matching media characteristics to the task needs. It categorized tasks based on uncertainty and equivocality. Tasks of uncertainty lacked sufficient information and could be executed by obtaining and sharing the needed information. Equivocal tasks, on the other hand, were those that had multiple and possibly conflicting interpretations of the available information, presenting a challenge for participants to arrive at one shared meaning of the information.

MRT also postulated that media varied in information richness (later called media richness) based on their capacity to facilitate this shared meaning within a given time interval. The theory asserted that four factors influenced a medium's information richness: the ability of the medium to transmit multiple cues (e.g., vocal inflection, gestures), immediacy of feedback, language variety, and the personal focus of the medium. Information richer media, the theory claimed, enabled users to communicate more quickly and to better understand ambiguous or equivocal messages and, therefore, would lead to better performance on equivocal tasks. In contrast, leaner media were better for low equivocality tasks because information rich media provided communicators with too much information and superfluous messages. Thus, Daft and Lengel [6] concluded that the use of information richer media (such as face-to-face meetings) would lead to better performance for equivocal tasks (such as deciding whether to acquire a company; p.558), while use of leaner media (such as written memos) would lead to better performance for less equivocal tasks (such as determining customer reactions to product labels; p. 558).

MRT has been the subject of many academic studies over the years, with no clear and compelling evidence to support it. Several researchers have extended and improved MRT over years, including most recently, Channel Expansion Theory [2]. At this point, most researchers would probably agree that media do differ in information richness, but the performance effects of using or not using information rich media for equivocal tasks is still an open debate [e.g., see 7].

A more recent theory, Media Synchronicity Theory (MST) [8] argues that there are two fundamental communication processes: the conveyance of information and the convergence on its shared meaning. Conveyance, particularly for large or complex information, is best done

through asynchronous digital media such as e-mail, while convergence, particularly for complex information, is best done through "richer" synchronous media such as face-to-face or telephone communication. For most complex (or equivocal) tasks, the use of asynchronous digital media (to exchange information and enable deep deliberation of its meaning) followed by synchronous media is preferred.

MRT and MST influence the workings of many virtual teams profiled in previous research. When equivocality exists, the customary reaction is to move the team to the information richest media possible for discussion: when there are multiple viewpoints, meet face-to-face or schedule a telephone conference [16].

In our study of global software development teams, we were interested in exploring the ways in which the teams coordinated and conducted their work. We anticipated finding the same general patterns as in prior research: work performed in virtual environments, coordinated by deep rhythms of information rich communication via face-to-face or telephone conversations.

3. Methodology

Because this was an exploratory project, we used an interview-based case study methodology [cf. 15, 16]. We studied four global software development projects in three firms, which we call TechCo, WorldCo, and StartCo (all names are pseudonyms). TechCo and WorldCo are two of the "big four" well-known Indian multinational firms that provide systems development and integration services to Global Fortune 500 clients. StartCo is a small start-up specializing in developing systems software for embedded systems and networking technologies.

We interviewed 12 employees (five from TechCo, four from WorldCo and three from StartCo) who had worked on global software development projects. Participants were selected based on professional contacts with the authors and by referrals from study participants to other participants in the projects in the study. The participants from TechCo and WorldCo had between 2 and 13 years of experience in global software development, while those from StartCo had 3-5 years experience.

All participants participated in semi-structured interviews conducted by the first author. Each tape-recorded interview lasted an average of 1.5 hours each. We contacted some participants by e-mail and telephone after the interview to clarify some of their remarks.

We asked participants to discuss a specific global software development project on which they had worked as a member of a virtual team that was representative of the projects on which they had worked. We collected data on three specific projects, one from StartCo and two for WorldCo. The manager who was our contact with TechCo was uncomfortable discussing specific projects with proprietary client information being tape recorded, so interviewees from TechCo were instructed to discuss "a typical project" without reference to a specific project.

As is common in field research, the data collection and data analysis stages overlapped. We continued to collect data at the same time as we were analyzing the results of previous interviews. The analysis of early interviews helped us refine our interviews and analyses of the later interviews [cf. 16]. Our initial analyses began with open coding using seed categories from prior research such as media use, equivocality, and temporal rhythms. We then added categories suggested by the data that added insight, such as repositories, and process structuring; see [20].

The planning and analysis of later interviews then exploited the categories we had developed; we used the categories to help structure and direct the later interviews. The information from these later interviews was then analyzed with the refined categories, but always with an eye to the potential for identifying new categories.

4. Results

In this section, we conduct within project analyses. In the Discussion section that follows we examine the patterns across the projects.

4.1 StartCo: Project 1

The project at StartCo (which we labeled "Project 1") required the team to port an existing StartCo system from Unix to NT and to integrate it with the U.S. client company's software. The 3-person team (project leader, technical lead, developer) worked intensively over a three month period.

Once the project leader "sealed the deal with the client" the technical lead was flown in from India to work with the client to identify the specific requirements. Given the short time frame of the project these requirements were captured in an informal requirements document. The technical lead also familiarized himself with those aspects of the client's software that were relevant to the integration. Once the requirements had been gathered the technical lead flew back to India and met (face-to-face) with the developer to communicate the requirements. The two of them developed a design document that was shared with the project leader (via e-mail). After the design had been finalized control was turned over to the developer who was primarily in-charge of the implementation.

The project started slipping and the technical lead was brought back to help complete the project. The plan was to have technical lead (now in the U.S.) and the developer (in India) to take advantage of the time difference and work on a 24-hour cycle (a "follow-the-sun" approach as described by Carmel and Agarwal [3]. At the behest of the project lead, the two of them exchanged status reports

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every day by telephone and sometimes via e-mail. The technical lead felt that this was important since questions asked via e-mails often left several questions unanswered or required a "synchronous" dialogue with the person on the other end. Code for the project (consisting of over 150 files) was exchanged through a common FTP server. Late every evening one of the team would upload the current version of the code to the FTP server and the other would download the whole project. Information about progress made during the day would be exchanged via the phone conversation at which point the other person would continue work on the system.

This approach worked to the team's advantage since they were able to complete the project on time. However, the technical lead expressed a lot of frustration with the hassles of coordinating this 24-hour activity. He observed that because of the time crunch both he and the developer would often not take the time to document their code as well as the changes made to the files since the last download. He observed that often they would forget to communicate all the changes and updates made during a given day to the other team member resulting in a lot of repeated work. For example, if he faced the same problem as the one faced in India they would waste their time figuring out the solution again. At the extreme they would rewrite each other's code. The use of high-synchronicity technologies did not serve all the needs of this team (despite the small size and complexity of this project).

In this project, we see the deep temporal rhythms of information rich communication reported in prior research. Information rich media (telephone calls) were used on a regularly scheduled basis to coordinate work between team members and work was to some extent driven by the regularly scheduled heartbeats of the phone conversations. Less information rich media (FTP) were used to exchange the content of the project work.

4.2 WorldCo: Project 2

One project at WorldCo (labeled "Project 2") was the development of an information retrieval engine, which took 11 months. At its peak, the project had six team members. Once the project was awarded to WorldCo the technical lead was flown to the U.S. from India to gather requirements through face-to-face meetings with the client. After the requirements were gathered and the high-level design was complete (and signed off by the client) the requirements were sent back (via an e-mail) to the development team in India was also briefed by the technical lead in a series of face-to-face meetings.

At this point, the team began the process of detailed design. Communication between the U.S.-based client and the project leader was limited and was usually done via e-mail. Infrequently, phone calls lasting about 1 hour were also scheduled to clarify aspects that could not be clarified via e-mail. It is worthwhile noting most of the e-mail communication between the client and the team in India was achieved through an intermediary, the project manager. The project manager was also responsible for the system's design documentation; each time a major change was made to a design document (e.g., the functional specification) a hard copy was printed and then signed and dated by the technical leader as well as the project manager. Once the project was completed then the final versions of the documents were moved to a repository for future access.

Once the detailed design was complete the team embarked on the implementation and coding phase of the project. During this phase the team used the Microsoft Visual Source Safe (VSS) repository to store all program code. VSS provided version control and recorded all changes to the code. Typically, one or more developers were allowed to check-out a given source file. The developers then made changes to the code and then checked it back into VSS. During check-in they were required to fill a standard form describing the changes made, why they made the changes, the effects that this change might have on other modules. VSS automatically creates a version of the file thus providing developers a complete history of changes to made every file that is part of the project. While the programmers would occasionally interact face-to-face and over the phone, the majority of task-oriented communication occurred through VSS.

Unit testing was conducted by the team in India. Every test plan was detailed using standard templates (concurrently with the design stage). These word documents would be updated as the testing progressed with data about which units succeeded/failed. Again, it was the responsibility of the project manager to maintain versions of these documents. Finally, during acceptance testing the client and the development team would communicate via e-mail. The client team would send bugs via e-mail to the project manager. Internally, the development team would (following the process guidelines established) fill out a bug tracking report (standard templates) for each report and the how they were fixed. A consolidated status report was sent back to the client at the end of each day.

The patterns found in prior research are less clear in this project. The team used an initial period of information rich face-to-face communication but use of information rich media dropped off quickly as the team moved into a greater global dispersion of the design phase. Less information rich media (e-mail) were used to issue and respond to queries, although information rich media were used infrequently. During implementation, a project repository (VSS) was used to coordinate the majority of the work, although information rich media were used on occasion.

4.3 WorldCo: Project 3

Another project at WorldCo (labeled "Project 3") was the development of a web-based workforce management system. This team worked just under 2 years and at its peak had 56 members, 10 in the U.S. and 46 in India.

The primary work processes in this project, not surprisingly, are very similar to the ones in the other WorldCo project above. During the initial phases, the team consisted of 10 people – 2 in the U.S. and 8 in India. The team in the U.S. communicated with the client and produced the requirements documents that were then shared via e-mail with the team in India.

A key difference between this project and Project 2, was that a digital version control mechanism was used to manager the design documents, rather than relying on the project manager. All design documents were shared through a common document repository. Team members would check-out one or more documents at any given time, make their changes and check them back in. They would then e-mail the rest of their team members indicating the availability of new or updated versions of a document(s). While the repository facilitated sharing of information among the team members the actual process used by the teams (during the high-level design and detailed design phases) were based on WorldCo's well-defined software design and development processes. For example, the functional specification for a given module (created by a team member in the U.S.) had to be reviewed by one other member of the team (who would most likely be in India). In such a case, the team member in India would check out the document, review it and then check it back in to the repository. The member would then send an email to the concerned parties, the author of the document as well as a member of the client team, and, if necessary, schedule a telephone conversation to discuss any unresolved issues. A similar process was followed during the detailed design phases also. It is worthwhile emphasizing that the outputs of each phase in the SDLC (e.g., high-level design documents) had to be in the repository with the appropriate approvals before work on the next phase was begun.

The details of the implementation stage for this project are very similar to those of Project 2, except that the version control tool used was Concurrent Version Systems (CVS) and not Microsoft VSS. Acceptance testing was somewhat different in this project in that communication among the team members was achieved using a bug-tracking system: the GNU Problem Report Management System (GNATS). Each bug report has associated with it a set of information such as, problem state, severity, priority, how to recreate the bug, etc. At WorldCo, whenever a bug was reported using this system, an e-mail was sent to the responsible parties (the developers in India). Whenever a bug was fixed, its status was updated in the bug tracking system thus minimizing the potential for redundant work. All interviewees said that for successful implementation of a project of this complexity using a global team the existence of the document management, code management and bug-tracking repositories was of prime importance.

Once again, the patterns found in prior research are less clear in this project. Information rich face-to-face communication was again used initially, but once again, use of information rich media dropped off quickly as the team moved into a greater global dispersion of the design, implementation and testing phases. Project repositories (CVS and a document repository) were used to coordinate the majority of the work, although information rich media were used on occasion.

4.4 TechCo: A Typical Project

As discussed in the Methods section, this section reports on a "typical" project at TechCo, rather than a specific project. Project planning and requirements definition is performed using a team at the client site, primarily through face-to-face meetings with the client. For small projects, this might be a 2 person team, while for large projects it could be a dozen or more. The onsite sub-team uses three primary media or technologies to communicate with the off-shore sub-team in India. A sophisticated home-grown document repository much like CVS is used extensively to manage all documents (e.g., requirements specifications, data models, process models), project schedules, and a configuration management tool all controlled through a check-in/check-out process is the primary media. There is a regularly scheduled once-a-week telephone conference call, while e-mail is used on an ad hoc basis in between.

The majority of the design and implementation phases are conducted at off-shore Software Development Centers, with only a small sub-team being present onsite. Once again, the U.S.-based team members and India-based team members use ad hoc e-mail, a regularly scheduled telephone conference call, and the repository to communicate with each other. Once again the repository is the primary media.

Finally, deployment (e.g., acceptance testing) is done at the client's site with only small support sub-teams in India, again using e-mail, telephone conferencing, and the repository to communicate among sub-teams.

Once again, the patterns found in prior research are less clear in typical projects at TechCo. Information rich face-to-face communication was used initially, but once again, use of information rich media dropped off quickly as the team moved into a greater global dispersion of the design, implementation and testing phases. A deep temporal rhythm of telephone conversation is used as the heartbeat of the project. Project repositories (CVS and a

home-grown document repository) were used to coordinate the majority of the work, although information rich media were used.

5. Discussion

From the analyses above it is clear that successful global virtual software development teams employ a myriad of technologies and work processes to successfully overcome the barriers faced by them. Prior research suggests that the use of information rich media such as face-to-face and telephone communication is important to successful global virtual teams, so much so that teams often create deep temporal rhythms of such information rich communication that serve as the heartbeat that drives the project [16].

We observed this pattern in Project 1 (in which team members used daily telephone calls to coordinate work for a "follow-the-sun" approach) and to some extent in the TechCo typical project. Carmel and Agarwal [3] discuss the extreme coordination complexity and problems that the follow-the-sun approach can create; we observed these same problems in Project 1. They argue that many global software development firms are moving away from this approach specifically because of the intense coordination and integration it requires. They offer several alternative approaches that can be used to reduce the coordination required.

A deeper analysis of Projects 2 and 3, and to some extent the typical project at TechCo 4 suggests a strikingly different pattern of interaction from that in Project 1 and those of prior research. While this pattern may be unique to these projects or companies, a review of the processes used at Infosys -- another of the "Big Four" Indian consulting firms and one not part of our study -- reveals similar patterns in use there [see 12].

Therefore, we conclude that the communication and coordination patterns we observed in these projects represent a different approach to communication and coordination in global virtual teams than that previously reported. Members of virtual teams communicate for a variety of reasons: to exchange work products, to coordinate activities, to socialize, to develop relationships, and so on. Work products in global software virtual teams are inherently electronic: they are software. Therefore is it obvious that regardless of the teams use or non-use of new digital media for other activities, they will use digital media for the exchange of work products. Thus digital media will play a central role in these teams. As we look at other types of virtual teams, we see similar electronic-based work products: project plans, proposals, financial analyses, mechanical drawings. Even in non-virtual teams, the digital exchange of information is common.

Perhaps the most distinguishing feature of virtual teams is the need to find new ways to augment or replace the traditional approach to coordinating work activities in traditional teams: the face-to-face meeting. Coordination is the division of work into distinct tasks and the coordination of the performance of those tasks [18]. In the sections below, we outline the major principles of communication and coordination for two different forms of virtual team organization we observed in these projects. We term the first the "Integrated Team," because it strives to improve communication and coordination by tightly integrating team members through information rich media. We term the second, the "Objected-Oriented Team," because many of the principles have parallels the object-oriented world.

5.1 The Integrated Team

The theoretical underpinnings of the integrated team approach (and the object-oriented team approach) lie in the work of Henry Mintzberg. He argues [18, pp. 3-9] that there are five fundamental approaches to coordination.

The first is *mutual adjustment*. Mutual adjustment requires that the members of the team work closely together to synchronize their efforts and is often used in very simple tasks (e.g., paddling a canoe) and in very complex tasks (e.g., putting a man on the moon) because it is both naturally and putatively the only way in which mutual experts can work on projects whose specific path is unknown at the outset.

The second is *direct supervision*, in which one person takes the responsibility of synchronizing activities. In effect, one brain thinks for the team and ensures that work is organized and coordinated.

Both of these approaches require that work activities of all team members be known to each other (mutual adjustment) or to the team leader (direct supervision). Communication is essential. The team is performing an elaborate ballet and all team members must be aware of the actions of others to perform well. Both mutual adjustment and direct supervision are commonly used in traditional teams and have also been carried over into the performance of virtual teams.

Communication and coordination processes used in traditional teams have long been guided (implicitly or explicitly) by media richness theory, which was developed before digital communication media were ubiquitous [6]. In the pre-digital era, media considered information rich were those capable of rapidly transmitting short snippets of communication simultaneously through multiple synchronous channels (e.g., face-to-face discussion with its spoken words, voice inflection, and non-verbal gestures). Information rich media improve communication by enabling synchronous

feedback that helps the sender to recognize the extent to which the receiver understands the message and to adjust the message presentation accordingly; a sender could recognize that the receiver understands the message and move on to new message(s), or recognize that the receiver does not understand the message and attempt to clarify it [4, 7]. Rapid feedback also enables the sender to use certain communication patterns that minimize the time required to achieve understanding [5].

However, such synchronous snippets discourage one activity that Weick [23] argues is important for sensemaking in the face of equivocality: deliberation, the slow and careful reasoning required to induce plausible patterns from information. When this reasoning is allowed to incubate, meaning becomes clearer; when information comes too quickly and immediate responses are required, individuals fail to process information and fall back on habitual processes and stereotypes [23]. Information rich media, with their synchronous and immediate focus have the potential to reduce deliberation [8], leading to poorer outcomes.

Thus, in traditional face-to-face teams and many virtual teams we see a digital exchange of information to permit deliberation followed by its discussion using a rich media. Maznevski and Chudoba [16] for example, observed that successful virtual teams using the integrated team approach developed a deep temporal rhythm of information rich face-to-face communication for coordination. Work was done between meetings and exchanged digitally in preparation for this burst of information rich exchange. In such integrated virtual teams, a lack of such a rhythm reduced effectiveness. The key to success in integrated teams is the tight coupling and integration of work and team members through both lean digital media and more information rich media.

5.2 The Object-Oriented Team

While mutual adjustment and direct supervision have long been used in face-to-face teams and increasingly by virtual teams who have explicitly or implicitly adopted those techniques, they are not the only mechanisms for coordination in teams. Mintzberg [18] defines three other approaches: *standardization of processes*, *standardization of inputs*, and *standardization of outputs*. With standardization of processes, the way in which is work to be performed is defined in advance, either very formally such as the assembly instructions for a child's toy, or less so, such as a requirement to get three bids for major corporate purchases. When outputs are standardized, the processes are left open, but the final result is well defined, such as taking a taxi: the route is left to the expertise of the driver, but the destination is not. When inputs are standardized, the skills of those performing the work are standardized. For example, when an anesthesiologist and a surgeon work together to remove an appendix, they hardly need to communicate; both know what to expect from the other, even though they do not know the details of the other's skills or processes.

By standardizing the processes, inputs or outputs, we can reduce communication between team members. No longer do we have a tightly coupled ballet but rather an assembly line. This leads to some strikingly different ways of organizing and coordinating work in virtual teams that builds on the work of Watson, Zinkhan, and Pitt [22] and their attempts to develop an object-oriented model of organizational strategy. In contrast to the traditional integrated virtual team approach, which strives to tightly *couple* team members through *information rich media*, the object-oriented team strives to *decouple* team members through the use of *semantically rich media*. It is well understood that tight coupling in the design of computer systems leads to problems [24]. When work and those that perform it are tightly coupled to other work and workers, a change in one area has ripple effects in others. It becomes increasingly difficult for the work to be performed independently because changes must be coordinated among the elements of the system [cf. 3]. The object-oriented team model shuns tight coupling in favor of a set of independent objects, which 1) have standardized or *well-defined processes*; 2) exchange information (inputs and outputs) with other objects through *well-defined semantically rich interfaces*; and 3) produce a *decreased flow of information*.

First, in contrast to most virtual teams studied in prior research, the teams in these projects used *well-defined processes and data*. Two of the organizations studied in these paper (TechCo and WorldCo) had been evaluated at level 5 of the Capability Maturity Model [19]; that is, their software development processes are well defined, documented, understood and enforced. Each phase of the project had clearly defined inputs and outputs and clearly defined rules for performing the work. For example, the output of the high-level design stage was a functional specification document created according to the companies' templates. A signed-off copy of this document served as the input to the detailed design stage. The use of standard templates for documents was identified as a key factor in facilitating effective communication among team members. It is also important to point out that while the processes and data were well defined, the assignments faced by these teams were not. There was considerable equivocality in the task requirements and changes to deliverables and processes did occur. Nonetheless, these object-oriented teams essentially worked to move equivocal new assignments through tried and true processes.

Second, the availability of clearly defined data and well-defined processes facilitated the second key element observed in these teams: communication and coordination

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among team members occurred mostly through well-defined messages passed via *semantically rich media*. Semantically rich media enable the transmission of information in containers that provide meaning beyond the information itself. These digital containers clarify, extend, and constrain the meaning of the information so that it is easier for the recipient to understand. Examples of such media included document repositories (e.g., DFDs, ERDs), code repositories, and bug repositories, all of which also tracked changes, comments about changes, and history data. All the interviewees agreed that the availability of these semantically rich repositories was "the most important thing" (as one interviewee put it). From a theoretical perspective, these semantically rich media enable the sender to edit and "rehearse" [8] the information to ensure the meaning is conveyed exactly as intended, and enable the recipient to "reprocess" [8] the message multiple times until the correct meaning has been extracted. They also usually enable the recipient to manage information complexity by providing search capabilities and different views of the information. Many automatically collect statistics and enable analyses of the information that would be practically impossible to collect from less semantically rich, but more information rich media such as face-to-face conversations; see [15] for an example of the problems of moving information from information rich to semantically rich media).

Third, the use of well-defined processes and semantically rich media to communicate and coordinate work, enabled the decoupling of team members and a *reduction* in the flow of information. One of the defining elements of an integrated team is the use of information rich media to share information widely among tightly coupled team members. In small, less complex projects, this may work well [18]; but as project complexity increases and the number of team members grows, this integration becomes problematic [18]. For example, consider the communication and coordination costs of the daily telephone call in Project 1 if there had been five, ten, or 50 team members. Once complexity goes beyond a certain level, it becomes impractical to communicate with information rich media; semantically rich media are needed to reduce the unneeded flow of information from the heavy "broadcast push" of coordination information sent to all team members via synchronous information rich media. Semantically rich media enable the "selective push" of coordination information (e.g., when the repository sends e-mails to those on a change notification list for each module) or the "selective pull" of coordination information (e.g., when the repository enables users to read the change history of each model with its attached comments as they need it).

In the object-oriented teams, communication and coordination among team members occurred mostly using semantically rich data media above. Nonetheless, information rich media were used by all object-oriented teams to *supplement* the semantically rich media. When synchronous information rich media were used (face-to-face meetings and telephone conversations), the information in the repository was the primary source of information about the project. If any change to information from a previous phase was made then there clearly defined criterion for communicating these changes such that they would get reflected in the documents from a previous stage. While objected-oriented teams relied primarily on the semantically rich media, they also used information rich media to effectively augment the semantically rich media (see Figure 1, next page). We see a pattern of media switching as in MST [8].

5.3 Implications

First and foremost, we need additional research on the object-oriented team model itself to seek additional evidence about its applicability beyond the organizations studied here. While it may be a useful organizing paradigm for virtual software development teams facing large and complex projects, we have no evidence of its usefulness in other environments.

The object-oriented teams used routine, mature work processes with well-defined task deliverables and the processes. Many of the projects undertaken by global virtual teams are often not well-defined repeatable or routine activities. Much prior research has focused on ad hoc virtual teams whose task is pioneering work in a new area, while other research has also included teams with long standing histories of working together on the same task for years [e.g., 15, 16]. We believe that some proportion of virtual teams do engage in routine processes -- processes that may not be formally well-defined but have the potential to be. Other virtual teams may work on projects new to them, but not new to the organization, projects that also have the potential to use well defined processes.

In the organizations we studied, we observed both "traditional" integrated virtual teams as well as object-oriented virtual teams. Thus while we believe that the object-oriented model of teams is important and useful, it certainly does not preclude the use of integrated virtual teams. One challenge for future research lies in understanding when each form of team is appropriate. Project complexity may be an important factor from both a theoretical and practical standpoint [18]. Prior research on virtual teams is replete with examples of integrated teams working on relatively small projects developed by the researchers and assigned to volunteers in experiments or small teams in field studies.

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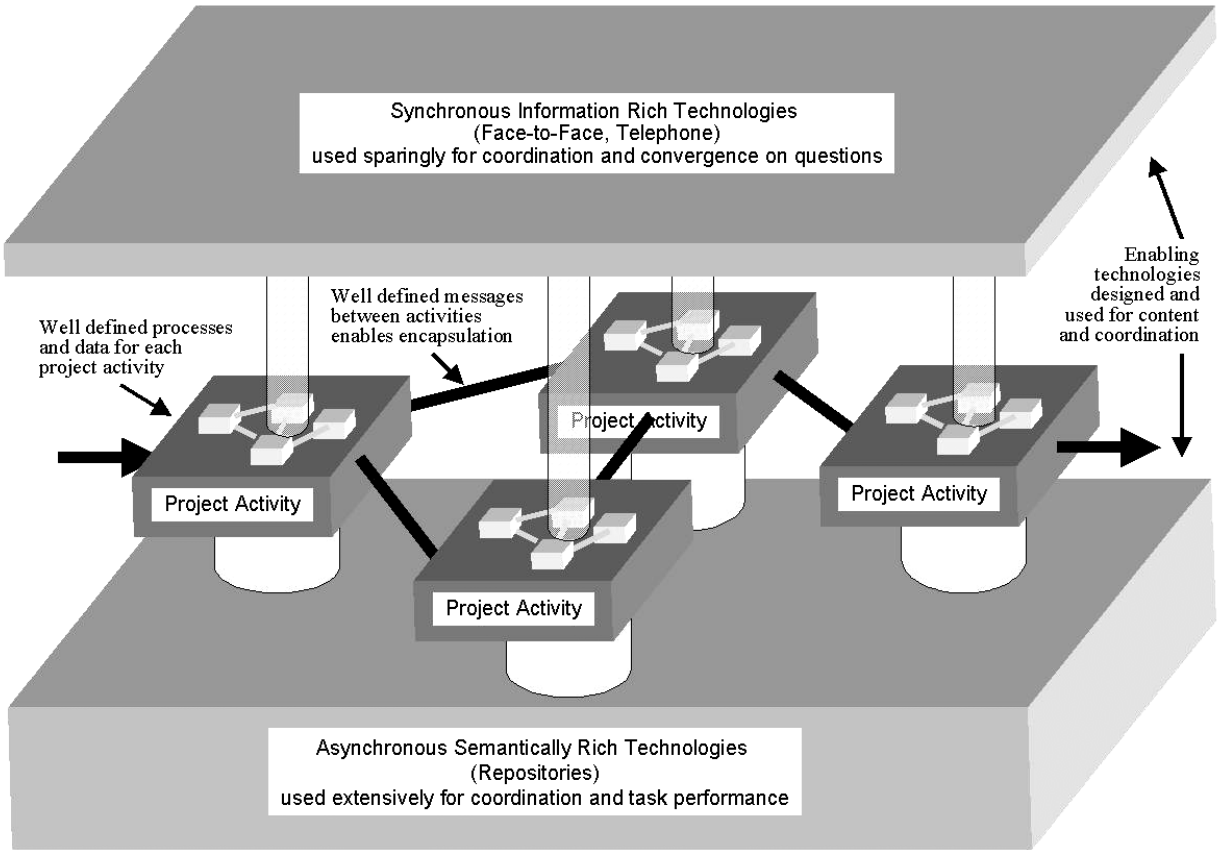
Figure 1: The Object-Oriented Team



In contrast, the object-oriented teams in this study were larger and/or worked for longer periods of time. As complexity increases and the number of team members who are needed to complete the project increases (whether from the sheer volume of work or from the need to include many specialists with unique skills), the complexity of communication and coordination via information rich media increases dramatically. One might argue that communication and coordination complexity increases as some proportion of the square of the number of team members because the number of potential linkages increases in this manner. This would suggest, for example, that communication and coordination in a 14-member team is almost twice as complex as that in a 10-member team. We speculate that the object-oriented team model may be most appropriate for large and complex projects, while the integrated team model may be most appropriate for smaller and less complex projects.

Research on virtual teams has tended to study communication issues such as trust, frequency of communication, and the information richness of the media. Much prior research has looked at media use in the context of the project as a whole. Our results suggest that it is important to study the use of media within phases and between phases. Our results also suggest that it is important to study the coordination of work activities as well as how those activities are performed. A critical aspect of future research may be to understand how to effectively combine the use of information rich old media with their inherent focus on the rapid exchange of short snippets of spoken text with the use of semantically rich new media with their focus on less rapid transmission of complex messages imbedded in digital containers.

We believe that the object-oriented team model may have important implications for practice. It has been used in the practice of software development, and we believe that it also may be usefully applied for virtual teams working in other areas. Thus, the first step for practice is to identify areas in which routine or repeatable work processes exist and to define the sub-processes team would use to accomplish those tasks. As Briggs et al. [1] argue, the key step in developing repeatable processes is

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the development of templates to guide the work processes that can be repeatedly and reliably involved (Briggs et al. term these templates "Thinklets"). Software development is a well defined, structured process; is it practical to suggest that we could develop similar highly structured processes for use in virtual teams? Certainly! Briggs et al. [1] provide several examples that have been developed and used in several organizations. The next step would then be to develop semantically rich tools and repositories to support those templates.

In conclusion, traditional virtual teams as reported in prior research have created tightly integrated teams connected via information rich media. In contrast, the object-oriented teams in this study strove to decouple team members through the use of well-defined processes and semantically rich media (e.g., repositories). These semantically rich media added meaning to the information by clarifying, extending, and constraining the information itself, and enriching it by collecting statistics, and providing the ability to filter and view the information in other forms. These semantically rich media reduced the flow of information compared to the broadcast push of information in synchronous information rich medium by enabling a selective push and/or pull of information, so that it was distributed only to those team members for whom it had value. The set of principles embodied in the object-oriented team we believe are applicable to many types of virtual teams, but especially larger teams facing complex problems.

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