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Gamel O. Wiredu
Interaction Design Centre
University of Limerick, Ireland
gamel.wiredu@ul.ie

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Summary
In this paper, I analyse how and why reducing task interdependencies and increasing information interdependencies constitute worthy strategies for managing interdependencies in the face of global-distribution of resources. The analysis establishes a relationship between spatiality and interdependencies, leading to expositions on the spatial rationales for task and information dependencies. Spatiality emerges as a predominant characteristic of task performance and information requirements. It underlines task and information as distinctive dimensions of interdependencies in distributed organising. Implications for task conceptualisation and design, for the bases of integration, and for contingencies of information processing in globally-distributed organising are drawn.

Keywords: interdependencies, tasks, information, spatiality, distributed organising.

Introduction

Interdependence is a concept that is of fundamental interest to organisational researchers. Seen as a direct antecedent of coordination, the importance of the concept is witnessed in how its conceptualisation has continuously preoccupied many organisational researchers over the years (e.g. Thompson, 2003; Thibaut & Kelley, 1959; Kelley & Thibaut, 1978; Van de Ven, Delbecq, & Koenig, 1976; McCann & Ferry, 1979; Kiggundu, 1981; Victor & Blackburn, 1987; Malone & Crowston, 1990, 1994; Wageman, 1995; Schmidt & Simone, 1996; Carstensen & Sørensen, 1996; Hoegl & Weinkauf, 2005). The concept has received explicit organisational research attention as researchers have explained it in the contexts of interpersonal relations (e.g. Kelley & Thibaut, 1978), of groups (e.g. Thibaut & Kelley, 1959), of interdepartmental relations (e.g. Thompson, 2003; Adler, 1995; Hoegl & Weinkauf, 2005) and of organisations and their task environments (e.g. Thompson, 2003; Jacobs, 1974; Van de Ven & Walker, 1984). These explanations have enhanced our understanding of the concept, but the virtual lack of explanation in the context of globally-distributed organising constitutes a challenge that needs addressing.

The literature on globally-distributed organising is replete with challenges such as conflicts (e.g. Hinds & Bailey, 2003; Jarvenpaa & Leidner, 1999; Mannix, Griffith, & Neale, 2002), inadequate mutual knowledge (e.g. Cramton, 2001), knowing (Orlikowski, 2002; Baba, Gluesing, Ratner, & Wagner, 2004), ethnocentrisms (Cramton & Hinds, 2005), attribution errors (Cramton, 2002) and innovation (Gibson & Gibbs, 2006). Explanations of these challenges point to three fundamental problematic sources: spatial and temporal distances between locations, and socio-cultural differences between globally-distributed workers. These sources and their associated challenges have been corroborated by many publications on global software development (see, for example, Sahay, Nicholson, & Krishna, 2003; Sarker & Sahay, 2004; Nicholson & Sahay, 2001; Carmel, 1999; Espinosa & Carmel, 2003; Krishna, Sahay, & Walsham, 2004; Herbsleb & Grinter, 1999; Herbsleb, Mockus, Finholt, & Grinter, 2000; Herbsleb & Mockus, 2003; Grinter, Herbsleb, & Perry, 1999). However, in spite of the corroboration, these publications as well as those on globally-distributed organising do not devote explicit attention to interdependencies.

Global software development (GSD) is a contemporary form of software development that draws heavily upon modern and advanced information and communication technologies to access global skilled labour, to form globally-distributed development teams, and to facilitate coordination of team members' distributed efforts. Carmel (1999), for example, talks about the deployment of best expertise, development and time-to-market costs reduction, global presence, and proximity to customers as some of the key motives that drive software companies to globally-distribute development tasks. Thus, going global is perceived to be of strategic value by software organisations that embark on such globalization and those that are about to. However, alongside this perception lies some scepticism both of which have engendered studies devoted to GSD recently. Many of these studies confirm that the strategic value to be gained from going global is as significant as the potential organisational challenges therein. A prominent aspect of these challenges is interdependence because the global-distribution of developers, of development tasks, of information and of technologies has strong potential to engender unsound interdependencies. This means that distribution of organising resources constitutes a peculiar source of these challenges in GSD. The peculiarity of global-distribution and associated unsound interdependencies increase the need for optimal interdependencies management therein. In short, optimal management of interdependencies is crucial for achieving strategic value in GSD.

But how are interdependencies managed in GSD, and why? Existing organisational research literature suggests that the challenges pertaining to managing interdependencies lie in what to do to constituents of interdependencies such as communications, work arrangements, work outcomes, rewards, and technologies in the contexts of interpersonal relations, groups, inter-unit relations, and inter-organisational relations. For example, Thompson (2003) focuses on the inter-unit context to conceptualize pooled, serial and reciprocal interdependencies; then he draws upon March and Simon (1993) to propose, respectively, managing by standardisation, by plan, and by mutual adjustment. Wageman (1995) and Wageman and Baker (1997) focus on managing task, outcome and reward interdependencies within groups. Malone and Crowston (1990; 1994) talk mainly about managing task-task, task-resources, and producer-consumer interdependencies within and between organisations. And McCann and Ferry (1979) speculate on the frequency of resource transactions, number of resources, and amount of resources exchanged per unit of time as the determinants of interdependencies management. The problem with these insights is that they are largely contextualised in collocated settings. Thus, it is clear that the question about interdependencies management in previous organisational research has not been posed in terms of global distribution of resources for software development.

Even in existing research on globally-distributed organising where general questions have been posed in terms of global-distribution, researchers have almost neglected the question about interdependencies management in these terms. Some of the existing literature on GSD that focus on coordination (e.g. Grinter et al., 1999; Herbsleb & Grinter, 1999; Herbsleb et al., 2000; Espinosa & Carmel, 2003; Espinosa et al., 2001; Sabherwal, 2003) provide some insights on interdependencies in GSD, but none conceptualizes interdependencies management explicitly. For example, Grinter and her colleagues (1999) talk about distance and interdependencies and, in fact, discuss collocation of task components as a coordination strategy (which this paper will likewise do). However, interdependence is not treated explicitly especially in terms of how distance affects it. Herbsleb and colleagues' (2000) analysis of distance, dependencies and delay in GSD talk about interdependencies, but they go only as far as explaining how distance and delay affect interdependencies between globally-distributed team members. And Herbsleb and Grinter (1999) talk about coordination challenges at the integration stage of software development against the context of Conway's Law; but they also do not conceptualize interdependencies management explicitly. In short, existing GSD insights do not give explicit attention to interdependencies management as it has been given in the literature on organisational research. These shortcomings in the general organisational research, as well as the specific globally-distributed organising and GSD research streams suggest that the practice of managing interdependencies in globally-distributed organising seems to be ahead of theory, and this calls for conceptualisation.

In this paper, I report findings on how Gamma, a globally-distributed subunit of a large multinational information technology organisation, was managing interdependencies in its global software development activities. My aim, first, is to conceptualize this practice within the context of GSD; and, then, to embed the conceptualisation in organisational research literature on task performance and information requirements. The spatiality underlying Gamma's teamwork would have potentially engendered serious conflicts, uncertainties and unsound interdependencies. But by reducing its task interdependencies and increasing its information (about tasks and strategy) interdependencies across sites concurrently, Gamma was able to manage uncertainties and conflicts which enhanced task performance and decision making. *Task* and *information*, therefore, constitute two distinct dimensions of interdependencies. Although the two dimensions are not mutually exclusive, the distinction is important because each requires a different treatment in terms of frequency of transactions to achieve optimal task performance and decision making in the face of spatiality. Previous research efforts have not conceptualized this distinction in spite of the acknowledgment that interdependence is a multidimensional concept (Thompson, 2003; Malone & Crowston, 1994; Wageman & Baker, 1997). If we come to understand why and how decreasing task interdependencies and increasing information interdependencies constituted worthy strategies for coordinating Gamma's GSD, we can learn valuable lessons on how to research and manage other globally-distributed research and development activities.

Research Setting

From early May to mid November 2006, Gamma, a globally-distributed team or subunit within Bork (a multinational information technology organisation) upgraded a data mining application (also called Gamma) for remote data collection from its customers' servers. The upgrade was a contribution to a larger application – GammaServ. GammaServ was, at the business or organisation level, aimed at supporting Bork's services to its customers. Several other subunits in Bork (labeled as Release Partners [RPs]) also contributed to the development of GammaServ. There were two releases that resulted in the final product – one in the first week of September and the other at the end of the upgrade in the second week of November.

Being weighed down by increasing costs caused by factors such as high cost of warranty on its hardware products, high operational costs, and effects of the dot.com bubble, Bork aimed to reduce the cost of warranty on its hardware products – "4% of 2005 revenue was put in the pot for warranty." Thus, driving down warranty cost was a priority, and supply chain and delivery costs had to be managed in this cost reduction. Bork envisaged that warranty cost reduction would be achieved through remote connectivity to customers' servers in which automated proactive data mining and diagnosing will manifest in those servers. It was also envisaged that this cost reduction would be achieved by relying on Bork's expertise around the world through information and communication technology to develop the data mining software. These led to the institution of GammaServ constituted by globally-distributed teams of which Gamma was one. Bork expected that globally-distributed team members would engage in both intra-team and inter-team technology-mediated communications to accomplish their tasks.

Gamma was constituted by twelve engineers: three developers and one Architect based in Kerry, Ireland; one support person and one developer based in Watertown, South Dakota (SD), USA; the Technical Lead (TL) and four developers in Bloomington, SD and one product release manager based in Los Angeles, California, USA. All twelve engineers reported to the Project Manager (PM) who was also based in Kerry in the same work area with the other four. Also, all twelve had been working as part of the Gamma team on earlier versions of Gamma before my empirical study. The team was formed specifically to develop the Gamma application in April 2004; thus, during the period of my study, all its engineers had been working together since the team's inception.

According to the PM, ideally, the nature of Gamma development required the hiring of more developers to get the work done, but there were strict budgetary constraints that barred him from hiring or allowing developers to travel across the Atlantic as frequently as would be appropriate for optimal coordination. And thus, Gamma's developers were required largely to seek expert advice and collaborate with developers in Watertown and in other Bork subunits elsewhere around the world in the process of Gamma development. However, the PM and architect made two trips per year to SD; one of the Kerry developers had travelled to both SD sites once before; and the TL, one Bloomington developer and one Watertown developer had travelled to Kerry once before on different occasions.

The time difference between Kerry and SD is 7 hours; thus there were few overlapping hours of work between the two locations. Gamma's very frequent project meetings were, therefore, usually held between 3.30pm and 6.00pm Kerry time. In times when the PM had to interact with Watertown developers necessarily, he usually worked from home (late in the Kerry day) to make use of more overlapping hours.

The SD developers were more experienced in developing remote connectivity applications than the Kerry developers. For example, the Technical Lead and two developers in Bloomington had been working together for over sixteen years on remote connectivity; and another Bloomington developer had been with them for 7 years. This contrasts with the two-to-three years of experience that characterised the Kerry developers.

Methods

This study was a theory development exercise and was, thus, founded on induction. The aim of my inductive approach was to understand how and why interdependencies in globally-distributed software development work are managed to get the work done. My seeking of this understanding translated into relying on observing and listening to teleconferences, on informal conversations and formal interviewing, on document studies and analyses, and on e-mail archiving as data collection methods. Apart from the formal interviewing of the six Gamma members that were interspersed with informal conversations in SD for a week, all the other methods were applied in Kerry where I spent most of the days in the study period (early July to mid November). I went to SD right after the final release of Gamma when the engineers there were less busy and could find time for my interviews.

Observing and listening to teleconferences were important sources of my data because teleconferences represented the main communication mode in which all of the engineers in Gamma participated and contributed. Through teleconferencing, mutual awareness among the team members was created regularly, the PM verified tasks statuses and assigned new ones, and participants engaged in collective discussions of pros and cons of new mini-proposals put forward by the PM. Thus, much of my appreciation of the high frequency of information exchanges, of how information was exchanged, and of the form and substance of the exchanged information were achieved by observing and listening to teleconferences. Apart from the main teleconferences in which all members of the team participated (or were supposed to participate), there were other mini-teleconferences held by fewer people working on particular components of Gamma, and these components were normally the focus of such mini-teleconferences.

There was at least one teleconference per week that involved all members of Gamma in mid-project (or normal) times; but as many as four per week could be held when the releases were approaching (hectic times). I participated as a silent observer in twenty of the teleconferences in which all members of Gamma participated over the study period. The times these teleconferences consumed ranged from one hour to two-and-half hours, many of them lasted approximately one-and-half hours, and all of them were held between 3.00pm and 7.00pm Kerry time.

I held several informal conversations with both the Kerry and SD engineers to fill the data gaps relating to my understanding of issues which they had discussed in teleconferences. Most of these informal queries related to just-completed meetings and others related to data gaps identified in my document analysis.

My interviews with the SD members were aimed at understanding their side of the story in terms of the data gaps and of my Kerry-based understanding of interdependencies and their management. Because I had just a week to spend with them in both Bloomington and Watertown, I found it more prudent to interview them with the aid of an interview guide, and the interviews were audio-recorded. I interviewed the Bloomington members individually to get personal perspectives from each of them, and I interviewed the two Watertown members together to gain data based on a collective perspective through their corroborations, modifications or refutations of each others’ responses to my questions. Apart from an interview with the SD Technical Lead which lasted about 70 minutes, each of the rest lasted about 45 minutes.

I also analysed the plans, reports (bugs and general), e-mail archives, schedules and presentations on Gamma throughout the study period. Because these various documents represented a massive collection, and because most of them could be accessed only from Bork's intranet, I spent several days poring over them at the Kerry worksite. My aim was to gain a background understanding of the Gamma setting (structure, aims, functions, roles, responsibilities, etc), and to enhance my continuous understanding of interdependencies and their management over the study period. Furthermore, these understandings were helpful in my data collection because they ensured that I asked the Gamma members only the searching or relevant questions. Given their busyness with their coding and communicative tasks, it was important that I did not bore them with queries which answers could be found in the Gamma archives.

Interdependencies management in Gamma development

Reducing task interdependencies

Gamma development was subdivided into components or tasks which were integrated eventually to result in the final product. In the face of the challenges posed mainly by spatial differences, the TL, who directed team affairs in terms of technical issues, redesigned the tasks to be less interdependent across the three sites. He said:

"*one of the things I tried to do in terms of task interdependencies as TL is to minimize those interdependencies especially between Kerry and Bloomington and Watertown…I tried to design the tasks so that they are completely independent between the regions. I would not necessarily actually do that if it's between two engineers on the same site….*"

According to him, the tasks had to be independent "otherwise they would take very very long times to finish." It is interesting to note that the TL's decision to make tasks more independent was not due particularly to the seven-hour time difference between SD and Kerry. Rather, his decision was due mainly to spatial differences between the three main locations. He said that even though Watertown and Bloomington had all their working hours overlapping because they were in the same time zone, "we still had to separate the tasks just because we're not physically together." His witness suggests that spatial distance is a predominant determinant of reducing task interdependencies in GSD. Spatial distance meant inadequate mutual awareness of what others in other sites would be doing until a teleconference was held; and this was a commonplace instance of uncertainty.

Note that the space criterion for reducing task interdependencies did not undermine the technical and experience criteria which are normally predominant in any software development activity. In fact, the technical and experience criteria facilitated largely the space criterion because the formation of the team itself could be defined as mobilization of Bork's global technical capabilities to match the task requirements of Gamma development. The team was composed of Bork's experts who could be found anywhere around the world. That is, the composition constituted the technical and experiential foundation for the leaders' adoption of the space criterion to reduce task interdependencies.

Increasing information interdependencies

The TL continued:

"*… Now when it comes to decisions about how to do [the tasks], we do collaborate – we try to force the people to come together on them*."

I discerned that the Gamma engineers engaged in many cross-site interactions. Apart from the weekly teleconferences involving all engineers, there were several other interactions in the form of phone calls, one-to-one and broadcast e-mailing, one-to-one and many-to-many instant messaging, posting of documents on the document management system, and assignment of bugs that was done by posting the bug details on the bug tracking system. The support person, who was based in Watertown and was the main link between the users (of Gamma's software) and the Gamma team, also relayed user-reported problems either to the appropriate subgroup or to the entire team to get them resolved. Such resolution, both at the subgroup and team levels, engendered several cross-site interactions to enhance mutual support between collective decision making and team cohesion.

Collective decision making focused on dealing with both internal and external facets of the engineers' work. Internally, the reduced task interdependencies threatened to reduce mutual task awareness. High levels of mutual task awareness were important because they ensured that operational problems were resolved early so that they did not become more difficult to resolve during eventual integration. Besides, high degrees of collective decision making were important because, periodically, the engineers faced strategic challenges that called for guidance from other engineers (especially the more experienced ones) to achieve resolution. Externally, continuously changing requirements from release partners and customers threatened to cause instability in operations. Such instability required the team's collective responsiveness through continuous team-level interactions.

Team cohesion reflected the need for relationship development among Gamma's engineers, and it could be achieved only through continuous interactions aimed at task awareness and collective decision making. Because of the reduced task interdependencies, there was potential danger for team members to exhibit inadequate mutual knowledge about their perceptual differences. Adequate mutual knowledge was crucial for increasing mutual understanding of information exchanged between them. The team drew upon this mutual understanding to remain responsive to changing requirements. In short, the threat to team disintegration was addressed by mutual learning through the frequent teleconferences and other technology-mediated interactions.

Measures instituted by the PM and TL (the leaders) to induce continuous cross-site interactions were the varied technologies that were availed to the engineers for supporting their varied communications, the occasional travels across the Atlantic, and his open allowance of agile development practices by the engineers. However, these measures were facilitated by the longevity of the engineers in the team.

Varied Technologies: The technologies deployed to support Gamma teamwork were e-mail, instant messenger (IM), telephone, Bugzilla® (a bug tracking application), Perforce® (a document management system), VirtualRoom® (a teleconferencing application) and Sharepoint® (a document sharing application used mainly in the VirtualRoom). These technologies exhibited variety because they supported varied communication modes (e-mailing, teleconferencing, telephoning, and instant messaging) and, hence, transmission of varied information representations (text, images, and voice).

Gamma engineers adopted the various technologies to match their varied circumstances such as the detail of information needed, the reckoned length of the communication, the nature of the problem, the engineer's personal communication preference, the time of the day, availability of the needed interlocutor, the need for traces, and the avoidance of repudiation. The varied technologies, communication modes and information representations, therefore, represented a functional measure that enhanced the high degree of interactions between the engineers in the three sites. And they contributed significantly toward both team cohesion and task accomplishment.

Travelling: The few trips made across the Atlantic by the few engineers were very significant both for sustaining the high level of cross-site interactions and for enhancing the quality of those interactions in terms of understanding.

In addition, the PM and the architect's two-trips-per-year to SD was significant in terms of motivating the more experienced Bloomington engineers and of discussing the team's strategic relationship with their release partners. I sat in a six-hour strategic meeting in Bloomington which had been occasioned by one of the PM's trips; and I realized the importance of the meeting to the team's strategising. This importance was also underlined by the Watertown engineers' presence. Although the PM would visit them in Watertown anyway, the importance of collective strategising in a face-to-face scenario induced their travelling to participate. Interestingly, the six hours were not even enough to "trash out all the issues;" but, certainly, they were extremely significant for the team's strategising because they could not have been able to discuss collectively for six hours nor could they have achieved that quality of strategic discussions through a teleconference.

Thus, although such trips and meetings were far fewer compared with the cross-site interactions, the engineers witnessed that travelling contributed significantly to increasing and sustaining the frequency of cross-site interactions, and to mutual understanding. Thus, travelling contributed significantly toward team cohesion and collective decision making.

Allowance of agility: The PM's open allowance of agile development by the engineers also contributed to task accomplishment; in particular, to the team' responsiveness to continuously changing requirements. This open allowance was significant because the official directive from Bork's directors was for teams to adopt formal methods for their development. In its cost-cutting agenda, Bork's directors were interested in ensuring that the engineers adopt formal methods and document those methods. However, what was manifesting was a form of development that they (the engineers and PM) all described as more agile than formal. Obviously, this was an instance of clear bending of the rule; but the bending, dictated by the continuously changing requirements, was almost mandatory if any work had to be done by the team.

Given the imposed formal development methods on Gamma by Bork, an outright discarding of the formal methods was out of question. The team, therefore, designed a tactic to be seen to be working with formal methods while, in reality, they followed agile methods. The Team Philosophy, for example, read as:

"*fast, lightweight, nimble... Do the Right Thing ...at the expense of 'the process*'"

And the Engineering Methodology also read as:

"*Our engineering methodology is a combination of a larger, traditional phased approach for use in outward-facing communications, and an internal iterative "agile" methodology for use within the team.*

The larger methodology is required because we interface with many external organisations that impose this structure upon our team. However, within the team we use an iterative form of the "agile" development methodology."

In spite of the allowance of agility, the team was also guided to some extent by structure, especially in terms of documentation of aspects of the work, where such documentation would not slow down the work. The PM needed such documentation to facilitate his reporting to his superiors and to the release partners.

The interesting aspect of the allowance of agility, however, is how it necessitated more frequent interactions in the face of continuously changing requirements. A team's agility is defined by how its members collaborate to respond to dynamic challenges that it faces. In the case of Gamma's engineers collaborations manifested in cross-site interactions. And since the changing requirements were continuous, their collaborations contributed to the increase in information interdependencies, and to team cohesion and decision making.

Longevity: The continuity of all the engineers in Gamma on the same project for at least three years was significant for the team's cohesion and sound collaborations. Such attributes can only manifest when team members develop a sound relationship through mutual understanding over a long time. Developing mutual understanding is a learning process essentially. And when the understanding is to be achieved predominantly through technology-mediated interactions because of global-distribution, the learning experience will last longer comparatively. In Gamma's case, the longevity of engineers on the team ensured the slow yet continuous mutual learning over time. The PM, for example, lamented about "guys making assumptions" in the early days of the project; and engineers in all three of the sites witnessed that they were learning continuously about the preferences of their fellow engineers in other sites.

The longevity of the engineers on the Gamma project, leading to increasing mutual understanding among the engineers, therefore, facilitated the increase in information interdependencies. Longevity was a facility because the sound relationship built upon their mutual understanding enhanced, on the one hand, their willingness to exchange information, and the quality of the exchanged information on the other.

Spatiality of task and information

Spatiality as an attribute of task performance

The spatial circumstances surrounding the reduction of task interdependencies in Gamma's teamwork raise the question: *how does space affect task performance?* Addressing this question is important to this research because it will provide theoretical explanations about why task interdependencies had to be reduced in Gamma's teamwork. Theoretical explanations beyond a simple explanation such as "…because we're not physically together," is, undoubtedly, needed for understanding the nature of tasks. These will lead to better management of and research on task interdependencies in other globally-distributed settings. Moreover, these explanations will show the relationship between spatiality and the main task attributes espoused in the organizational research literature.

Existing conceptualisations of organisational tasks suggest two main characteristics: variability and analyzability (Perrow, 1967; Van de Ven & Delbecq, 1974; Daft & MacIntosh, 1981). Task variability refers to the amount and frequency of exceptional events in the task, while task analyzability refers to the amount of exceptional actions or behaviours and of time required to deal with the work exceptions. The description of task variability mirrors Roby and Lanzetta's (1958) "objective" or inherent properties of tasks, summarized as "task qua task" by Hackman (1969). And the description of task analyzability reflects Roby and Lanzetta's (1958) "modal" properties of tasks that elicit particular behaviours; thus, Hackman (1969) labels it "task as behaviour requirement." Perrow (1967) and Daft and MacIntosh (1981) match variability against analyzability to describe categories of tasks and their technological requirements (see Figure 1). Thus, at one end are tasks characterised by both high variability and low analyzability that require non-routine technology (e.g. R&D work). And this contrasts with lowly variable and highly analyzable tasks that require routine technologies (e.g. assembly line work) at the other end.

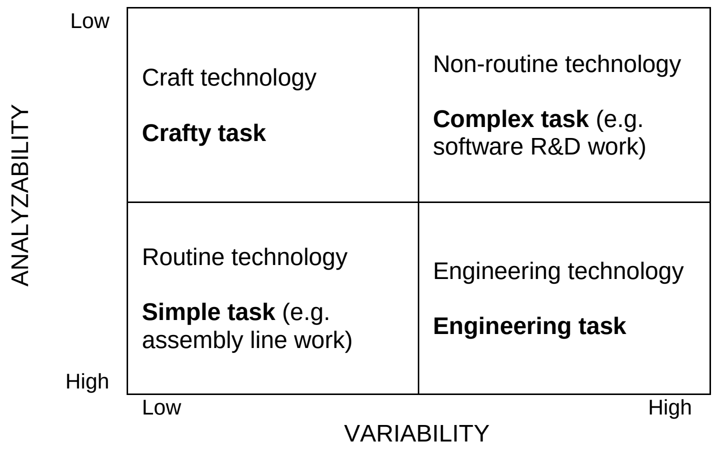
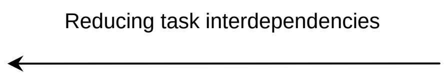


Figure 1: Relationship between task characteristics and technology requirements [Source: Amended from Perrow (1967)]

An analysis of Gamma's task performance, using Figure 1, signifies that the task was complex – highly variable and lowly analysable. On the one hand, it was highly variable because the constantly changing requirements at the business level engendered high degrees of exceptional events in the task. On the other, much of the problems in Gamma development were lowly analyzable because such exceptional events elicited exceptional behaviours such as agility. The upshot is that existing task conceptualisations exemplified by Figure 1 only go as far as explaining how variation and analysis make tasks more difficult. Such conceptualisations do not proffer sufficient capacities for explaining why task interdependencies were reduced in Gamma because they lack spatial constructs. The phrase "not physically together" in the TL's explanation suggests that space or location is a significant conditioner of the team's task performance, but this suggestion is not captured by Figure 1.

As I have already pointed out, Bork's decision to compose globally-distributed teams was based primarily on mobilizing the requisite engineers to match the task performance requirements, and this was regardless of the locations of these experts. This means that the original structuring of the team was duly inclusive of variability and analyzability considerations, but exclusive of spatiality considerations. Interestingly, the TL's reason for reducing task interdependencies was, essentially, one that signified his inclusion of spatiality considerations into the task performance frame. Reducing task interdependencies was, therefore, a restructuring exercise that acknowledged the fact that task performance is a function not just of variability and analyzability, but also of spatiality.

This acknowledgement can be explained by examining the relationships between these three task characteristics. Since the relationship between variability and analyzability has been examined already leading to Figure 1 (see Perrow, 1967; Van de Ven & Delbecq, 1974; Daft & MacIntosh, 1981; Daft & Lengel, 1986), an examination of the relationship between spatiality on the one hand and the examined outcomes of Figure 1 on the other will suffice for our needed explanations. In this examination, the spatial dimension is defined by *collocated* and *distributed* as variables because reducing task interdependencies was a task re-locating exercise. And the variability-analyzability dimension is defined by *complex* and *simple* as variables because they represent extreme characteristics that, together, embody other tasks requiring craft and engineering technologies (see Figure 2).



VARIABILITY-ANALYZABILITY (Complex – Simple)

	Collocated	Collocated-and-distributed	Distributed
Complex	**1.** <u>**Task**</u> **Complex:** All components collocated (e.g. traditional software R&D work) **Spatiality (collocation) facilitates efficient performance**	**2.** <u>**Task**</u> **More complex:** Overall task distributed but components collocated (e.g. software R&D work performed by collocated subgroups but the subgroups are globally-distributed) **Spatiality (collocated-distributed) facilitates efficient performance**	**3.** <u>**Task**</u> **Overcomplicated:** All task components distributed regardless of location (e.g. software R&D work performed by individuals who are globally-distributed) **Spatiality (extreme distribution) retards efficient performance**
Simple	**6. Simple**	**5. Less simple**	**4. Least simple**

SPATIALITY OF TASK

Figure 2: Revised task model showing relationships between spatiality, variability and analysability

A re-analysis of Gamma’s task performance, using Figure 3, now signifies that the task would have been overcomplicated had the team operated according to the original structuring of the task – highly variable, lowly analyzable and highly distributed. Although the Gamma engineers were not as distributed as the example in Cell 3 shows, the task would have exhibited overcomplication anyway because the engineers in different locations would work highly interdependently on particular components of the task. Disregarding spatiality in the original structuring would have contributed to overcomplicating an already complex R&D task. The task would have been overcomplicated because even its ordinarily complex version (Cell 1) requires interactions that are not just oral but also face-to-face, informal and spontaneous (see March & Simon, 1993; Allen & Cohen, 1969; Gerstberger & Allen, 1968; Katz & Tushman, 1979; Tushman & Nadler, 1978). Because people’s interactions are essential to task structure and performance (Perrow, 1967), especially to group tasks, extreme distribution would have affected the interactions of those who would perform those tasks. This is because the people would be distributed, and their interactions would be devoid of favourable interactions. To wit, distribution affects task performance because it can displace the favourable interactions that are necessary for task performance.

Thus, without the TL’s intervention – that is, his reduction of task interdependencies (his restructuring) – the Gamma team would have performed overcomplicated tasks devoid of favourable interactions that are crucial for the requirements of such a task. Without his intervention, a scenario where task requirements are greater than the arrangements to perform them would manifest, signifying an imbalance. Since extreme distribution supplants “favourable interactions” – oral, face-to-face, informal and spontaneous communications –, it can be considered as the main cause of inefficiency that was exemplified in the TL’s explanation: “otherwise they would take very, very long times to finish.” The reduction of task interdependencies by re-locating the components restored some favourable interactions to the team’s task structure and increased their performance efficiency.

In short, spatiality is a significant task attribute. Task performance depends on ‘fixing’ space because the degree of distribution of task components is a determinant of task performance. A task is not defined merely by the degrees of manipulation of variability and analyzability which the task brings to the fore: the degree of spatial manipulation which is brought to the fore is also integral to the definition. Thus, a revised task performance model

(Figure 2) which incorporates task variability, analyzability and spatiality proffers greater capacity for analysing task performance.

Spatiality as an attribute of information requirements

The collocation of task components in response to the task's spatial demands, at the same time, undermined collective decision making by Gamma. Collective decision making was going to be more difficult because of the distribution of tasks and team members; and team cohesion was considered a significant facilitator of collective decision making. A distributed team's cohesion reflects a state of adequate mutual understanding and well-developed relationships among its members through information generation, sharing and processing. Daft and Lengel (1986) inform us that information generation and processing correspond respectively with task variability and analyzability. However, the empirical case in this paper also informs us that, in addition to generation and processing, Gamma's task spatiality required information sharing for team cohesion and collective decision making. It is interesting, therefore, to examine how information sharing relates with generation and sharing.

The relevant question is: *how does space affect collective decision making*? This question is important because addressing it will explain why information sharing – and not just generation and processing – is a predominant variable of information requirements for globally-distributed work. Addressing this question will also contribute partly to developing theory for explaining issues such as increasing information interdependencies across sites in globally-distributed work.

Two main contingencies have been applied to analyse organisational information requirements – uncertainty and equivocality (Daft & Lengel, 1986). Uncertainty in an organisation is understood as the absence of needed information or as an entity's inability to predict information about a task accurately; and, thus, managing uncertainty is achieved by generating more information. Equivocality, on the other hand, means ambiguous information, ambiguity borne of various and inconsistent interpretations of an organisational situation (Weick, 1979; Daft & Lengel, 1986; Daft & MacIntosh, 1981). Therefore, managing equivocality is achieved by processing information on hand. Weick (1979), for example, stresses on managing equivocalities through other means apart from generating more information. Daft and Lengel (1986) integrated these two contingencies into a framework of information requirements, and traced the source of the requirements to task characteristics – variability and analysability (Perrow, 1967; Van de Ven & Delbecq, 1974). Thus, for example, complex tasks (highly variable and lowly analyzable) are characterised by high uncertainties and high equivocalities, and so they require high information generation and high information processing. Conversely, simple tasks require low information generation and low information processing because they are lowly uncertain and lowly equivocal (see Figure 3).

UNCERTAINTY

Low High

ANALYSABILITY (Low – High) / EQUIVOCALITY (High – Low)

1. **Crafty Task** • lowly variable, lowly analyzable **Information characteristics** • lowly uncertain, lowly analyzable	**2.** **Complex Task** • highly variable, lowly analyzable **Information characteristics** • highly uncertain, highly equivocal
4. **Simple Task** • lowly variable, highly analyzable **Information characteristics** • lowly uncertain, lowly equivocal	**3.** **Engineering Task** • highly variable, highly analyzable **Information characteristics** • highly uncertain, lowly equivocal

Low High

VARIABILITY

Figure 3: Relationship between task and information characteristics

We have already come to terms with the fact that this model (Figure 3, virtually the same as Figure 1) is insufficient for analysing distributed organising because it does not capture the intrinsic yet determinant spatial variables. Thus, Figure 2, which incorporates spatial variables, is drawn upon to explain how space affects team cohesion in distributed organising. The resultant (Figure 4) shows the information characteristics, needs, interactions and requirements of complex tasks. Thus, among the qualities of *more complex tasks*, for example, unshared and misunderstood information, task awareness and team cohesion stand out as qualities that confirm space as a significant variable of both task and information.

VARIABILITY-ANALYZABILITY (Complex – Simple)

1. Complex Task Information characteristics • unshared (easier to share) • collocated and misunderstood (easier to understand) Critical needs: • collective decision making Interactions • face-to-face • spontaneous formal and informal Information requirements • low information sharing • high information generation • low information processing	**2. More Complex Task** Information characteristics • unshared (more difficult to share) • misunderstood (more difficult to understand) Critical needs: • collective decision making • task awareness • team cohesion (mutual learning) Interactions • technology-mediated • pre-meditated • mainly formal Information requirements • high information sharing • high information generation • high information processing	**3. Overcomplicated Task** Information characteristics • unshared (most difficult to share) • highly misunderstood (most difficult to understand) Critical needs: • collective decision making • task awareness • team cohesion (mutual learning) Interactions • technology-mediated • pre-meditated • mainly formal Information requirements • higher information sharing • high information generation • high information processing
6. Simple	**5. Less simple**	**4. Least simple**

Collocated Collocated-and-distributed Distributed

SPATIALITY OF TASK AND INFORMATION

Figure 4: Task and information characteristics depicting the role of spatiality

These qualities add more sense to why more frequent interactions among Gamma engineers across sites was necessary for the team's mutual learning and cohesion. They also show that unshared information is a pervasive problem confronting information requirements and, hence, of distributed team members' performance of more complex tasks. Thus, recalling the measures that ensured increased information interdependencies, varied technologies were mainly deployed to support information generation, processing and sharing; travelling facilitated information sharing and processing; agility facilitated information sharing and processing; and longevity facilitated information generation and sharing. It follows from these that information sharing was as important as generation and processing; hence, information *sharedness* is as critical as uncertainty and equivocality.

Discussion

Given how critical the spatiality of task and information is, it is important to relate spatiality to interdependencies management. This relationship will explain why reducing task interdependencies and increasing information interdependencies across sites are worthy strategies for managing interdependencies in GSD organisation.

The preceding analyses suggest that, in the face of spatial distribution, task variability and analyzability are not the only reasons for managing task interdependencies; and this challenges previous research (see, for example, Perrow, 1967; Van de Ven & Delbecq, 1974). Task spatiality affects both variability and analyzability to determine task performance. It affects analyzability because distribution of task components undermines the favourable interactions that complex tasks require for accomplishment. Favourable interactions represent the "particular behaviours" (Roby & Lanzetta, 1958) that make up the "exceptional actions" (Van de Ven & Delbecq, 1974) elicited by task variability. By undermining favourable interactions, pieces of information are likely to remain misunderstood, leading to equivocalities. Favourable interactions are innately information processing actions that reduce such equivocalities because they enhance information sharing and understanding immensely. All of these mean that the greater the task interdependencies between locations in a GSD team, the greater will be the unshared and equivocal information for decision making, and vice versa. Therefore, managing interdependencies across sites by reducing task interdependencies is a way of increasing information sharing and processing pertaining to collocated task components.

However, by reducing task interdependencies, variability pertaining to collocated task components and overall task increase because the collocation is a disincentive to cross-site interactions. That is to say, task spatiality affects variability. This disincentive is affected by spatiality because collocation of components facilitates favourable on-site interactions at the expense of cross-site interactions and relationship development. In performing complex tasks, the collective decision making at the team level (not at the site level) aims at dealing with exceptional task variations such as continuously changing software requirements from outside the team. Exceptional task variations, undoubtedly, proceed to affect the collocated task components; and they will coerce distributed teams to readjust. The challenge facing readjustment relates to the degree of mutual learning and relationship development among team members, two parameters that bear significantly on information sharing and generation for optimal decision making. In short, collocating task components by reducing task interdependencies reduces information sharing and generation across sites. Therefore, while managing interdependencies by reducing task interdependencies reduces local equivocalities, the same procedure increases cross-site uncertainties concurrently. In other words, task interdependencies are negatively related to uncertainties because of spatiality.

The negative correlation between task interdependencies and uncertainties contrasts with Daft and Lengel's (1986) argument that interdependencies between departments correlate positively with uncertainties. The fact that Daft and Lengel's research deals with inter-departmental interdependencies while my research deals with intra-team interdependencies may account partly for the contrasting arguments. But the spatial factor seems to be more accountable because if departments are spatially-separated considerably, the low interdependencies may result in greater coordination stability and certainty as Daft and Lengel claim, but the stability and certainty will be purely task-related. By adopting an information perspective, however, one can be sure that each department will be largely uncertain of what the other knows or does because of reduced interactions between them.

The preceding analyses also suggest that in the face of spatial distribution, uncertainty and equivocality are not the only reasons for managing information interdependencies; and again, this challenges previous research (see, for example, Allen & Cohen, 1969; Van de Ven et al., 1976; Galbraith, 1977; Tushman & Nadler, 1978; Weick, 1979). The degree of sharedness and of mutual understanding of information (that is, the spatiality of information) shapes uncertainty and equivocality respectively to determine optimal collective decision making. Information sharedness affects uncertainty because unshared information reduces information generation. In shared information scenarios, exemplified by collocated teamwork, the information generator is mainly concerned with what information and how to obtain it. However, in unshared information scenarios, exemplified by distributed teamwork, *where* to get the information becomes an additional concern for the information generator.

However, even if information is shared significantly owing to increased information interdependencies, mutual understanding is not a guarantee because of possible perceptual differences that can undermine mutual knowledge. When the same piece of information is held by two people with perceptual differences, they are bound to generate different sets of knowledge from the information according to their perceptual differences. Thus, knowledge is context-based essentially; and in globally-distributed teams, the context can be anything from national or tribal culture, to religion, to familial upbringing, to professional training and to environmental influence. In collocated scenarios, it is easier and quicker for mutual learning and understanding to manifest among team members. Inadequate mutual knowledge is, therefore, an instance of equivocality because it signifies multiple meanings of the same information held by different people (Daft, Lengel, & Trevino, 1987). This means that spatiality affects equivocality by virtue, first, of global distribution of the holders of the different meanings; and, second, of increasing the efforts needed for information processing to achieve mutual knowledge. It also means that spatiality is a significant reason for reducing information interdependencies. The upshot is that managing interdependencies by increasing information interdependencies across-sites is a way of increasing information sharing and generation pertaining to overall task performance.

Spatiality as a critical dimension of both task and information, therefore, underlines the distinctiveness of task and information in this organising context as the core dimensions of interdependencies. And it justifies reducing task interdependencies and increasing information interdependencies as worthy strategies for ensuring optimal task performance and decision making in globally-distributed organising.

Implications

The explanations for task interdependencies imply that spatiality considerations need to be incorporated in task conceptualisation and related design decisions, especially in globally-distributed organising. Considerations of task characteristics such as variability and analysability (Perrow, 1967; Daft & Lengel, 1986; Van de Ven & Delbecq, 1974) autonomy (Hackman & Oldham, 1976) and experienced responsibility (Kiggundu, 1981) must incorporate spatiality because it bears significantly on task performance even in collocated settings (Hatch, 1987). The key to this consideration is *where*. Where a task is being performed will determine how efficiently it is performed and how related information is generated and processed, and this consideration will better inform the management of task interdependencies.

To this end, task design decisions, especially those concerning integration of organizational departments or distributed team locations, cannot be solely based on differentiation (Lawrence & Lorsch, 1967). Differentiation refers to the degree of separation of departments based on how their tasks or intermediate goals differ; and integration is the process of achieving unity of effort among such differentiated departments. This paper suggests that the degree of distribution is an additional basis of integration. Thus, the relevant question for integration is not merely the degree of differentiation between an organisation's departments. Rather, it is of the degrees of both differentiation and spatial distribution of an organization's departments or of its subunit's resources. The analyses show, for example, that extreme forms of distribution (rather than mere differentiation) can dominate the need for integration.

Spatiality also has implications for the contingents of "information processing" in organisational design (Tushman & Nadler, 1978). Note that Tushman and Nadler's use of "information processing" includes information generation and is thus different from my usage of the term in this paper. "Information requirements" seems to be a more appropriate generic term for information processing, sharing and generation, but I will use "information processing" just to explain this implication in this paragraph. Tushman and Nadler hypothesized subunit task characteristics, subunit task environment, and inter-unit interdependence as the three main sources of uncertainties and of information processing requirements in organisational design. However, the criticality of spatiality suggests a fourth source which they did not address: intra-unit interdependencies. The analysis of spatiality suggests that regarding intra-unit interdependencies – the task and information dimensions, in particular – will make "information processing" theory more relevant and valuable for analysis of "information processing" in globally-distributed organising.

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