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Research Papers

Referred Journal Articles

"Time Separation, Coordination, and Performance in Technical Teams ", Espinosa, J. A., Cummings, J. N., Pickering, C., IEEE Transactions on Engineering Management (2011 in press).

Technical teams are often distributed across geographic locations and across time zones. While spatial and time separation are often correlated, most prior studies have only focused on one or the other. As a consequence, their respective effects may be confounded when teams have both spatial and time separation. We argue that bridging spatial and time separation pose very different coordination challenges, thus their respective impacts need to be examined together to fully understand how geographic configuration influences team performance. We report on a field study of 123 technical teams conducted at a large semiconductor manufacturing company where we investigated how spatial and time separation influenced team performance. Our results show that time separation, in the form of maximum time zone difference spanned by members, has a stronger negative impact on team performance than spatial separation. We also show that this impact is indirect – i.e., large time zone spans create coordination problems, which in turn impact team performance. Put differently, when coordination problems are reduced, the negative association between maximum time zone span and performance disappears. We describe our findings and discuss implications for global team managers and collaboration tool designers.

"Coordination and Performance in Global Software Service Delivery: The Vendor's Perspective", Gopal, A., Espinosa, J. A., Gosain, S., Darcy, D. P., IEEE Transactions on Engineering Management (2011 in press).

Past research on software development outsourcing has explored in some detail the client's perspective and its attendant performance issues. However, relatively few studies have explicitly addressed performance drivers viewed from the vendor side. In this paper, we fill this gap by examining how coordination within the project team and between the client and the vendor organizations influence two dimensions of software project performance – software quality and

development speed – using data from 83 software projects from nine Indian software firms. Our results show that both client (external) coordination and vendor team (internal) coordination positively influenced software quality, but not development speed. We also found that client communication barriers moderated the impact of coordination with the client on quality. While we did not find that vendor team coordination affected development speed, team size had a negative interaction effect with vendor team coordination on development speed. Interestingly, temporal boundaries had a detrimental effect on software quality, but a positive effect on development speed. Finally, we found that development speed increased with the number of person days devoted to the project up to a certain point (i.e., a first order effect), but speed declined with additional person days (i.e., a second order effect). Our findings contribute to literature and practice by offering nuanced insights into performance in outsourcing projects from the vendor perspective and the role of coordination, both within the vendor team and with the client.

"Follow The Sun: Workflow In Global Software Development: Conceptual Foundations", Carmel, E., Espinosa, J. A. and Dubinsky, Y. (2010). Journal of Management Information Systems, 27(1): 17-37. 

Follow The Sun (FTS) has an interesting appeal – hand-off work at the end of every day from one site to the next site many time zones away in order to speed up product development. While the potential impact on "time-to-market" can be profound, at least conceptually, FTS has enjoyed very few documented industry success cases because it is widely acknowledged that it is extremely difficult to implement. In order to address this "FTS challenge" we provide in this paper a conceptual foundation and formal definition. We then analyze the conditions under which FTS can be successful in reducing development duration. We show that handoff efficiency is paramount to successful FTS practices and that duration can be reduced only when lower within-site coordination and improved personal productivity outweigh the corresponding increase in cross-site coordination. We also develop 12 research propositions based on fundamental issues surrounding FTS: calendar efficiency, development method, product architecture and hand-off efficiency, within-site coordination, cross-site coordination, and personal productivity. Finally, we describe our FTS exploratory field studies and draw out key findings and learning.

"Crossing Spatial and Temporal Boundaries in Globally Distributed Projects: A Relational Model of Coordination Delay", Cummings, J., Espinosa, J. A. and Pickering, C. (2009). Information Systems Research, 20(3): 420-439.

In globally distributed projects, members have to deal with spatial boundaries (different cities) and temporal boundaries (different work hours) because other members are often in cities within and across time zones. For pairs of members with spatial boundaries and no temporal boundaries (those in different cities with overlapping work hours), synchronous communication technologies such as the telephone, instant messaging (IM), and Web conferencing provide a means for real-time interaction. However, for pairs of members with spatial and temporal boundaries (those in different cities with non-overlapping work hours), asynchronous communication technologies, such as e-mail, provide a way to interact intermittently. Using survey data from 675 project members (representing 5,674 pairs of members) across 108 projects

in a multinational semiconductor firm, we develop and empirically test a relational model of coordination delay. In our model, the likelihood of delay for pairs of members is a function of the spatial and temporal boundaries that separate them, as well as the communication technologies they use to coordinate their work. As expected, greater use of synchronous web conferencing reduces coordination delay for pairs of members in different cities with overlapping work hours relative to pairs of members with non-overlapping work hours. Unexpectedly, greater use of asynchronous e-mail does not reduce coordination delay for pairs of members in different cities with non-overlapping work hours, but rather reduces coordination delay for those with overlapping work hours. We discuss the implications of our findings that temporal boundaries are more difficult to cross with communication technologies than spatial boundaries.

"Familiarity, Complexity and Team Performance in Geographically Distributed Software Development", Espinosa, J. A., S. A. Slaughter, R. E. Kraut and J. D. Herbsleb (2007), Organization Science, 18(4), p.613-630. 

While prior research has found that familiarity is beneficial to team performance, it is not clear whether different kinds of familiarity are more or less beneficial when the work has different types of complexity. In this paper, we theorize how task and team familiarity interact with task and team coordination complexity to influence team performance. We posit that task familiarity is more beneficial with more complex tasks (i.e., tasks that are larger or with more complex structures) and that team familiarity is more beneficial when team coordination is more difficult (i.e., for larger or geographically dispersed teams). Finally, we propose that the effects of task familiarity and team familiarity on team performance are complementary. Based on a field study of geographically distributed software teams, two of our hypotheses are disconfirmed: Our results show that the beneficial effects of task familiarity decline when tasks are more structurally complex and are independent of task size. Conversely, the hypotheses for team familiarity are confirmed as the benefit of team familiarity for team performance is enhanced when team coordination is more challenging—i.e., when teams are larger or geographically dispersed. Finally, surprisingly, we find that task and team familiarity are more substitutive than complementary in their joint effects on team performance: Task familiarity improves team performance more strongly when team familiarity is weak and vice versa. Our study contributes by revealing how different types of familiarity can enhance team performance in a real-world setting where the task and its coordination can be highly complex.

"Learning From Experience In Software Development: A Multi-Level Analysis", Boh, W. F., S. A. Slaughter and J. A. Espinosa (2007), Management Science, 58(3), p.1315-1331.

This study examines whether individuals, groups, and organizational units learn from experience in software development and whether this learning improves productivity. Although prior research has found the existence of learning curves in manufacturing and service industries, it is not clear whether learning curves also apply to knowledge work like software development. We evaluate the relative productivity impacts from accumulating specialized experience in a system, diversified experience in related and unrelated systems, and experience from working with others on modification requests (MRs) in a telecommunications firm, which uses an incremental software development methodology. Using multilevel modeling, we analyze extensive data archives coveringmor e than 14 years of systems development work on a major

telecommunications product dating from the beginning of its development process. Our findings reveal that the relative importance of the different types of experience differs across levels of analysis. Specialized experience has the greatest impact on productivity for MRs completed by individual developers, whereas diverse experience in related systems plays a larger role in improving productivity for MRs and system releases completed by groups and organizational units. Diverse experience in unrelated systems has the least influence on productivity at all three levels of analysis. Our findings support the existence of learning curves in software development and provide insights into when specialized or diverse experience may be more valuable.

"Team Knowledge and Coordination in Geographically Distributed Software Development", Espinosa, J. A., Slaughter, S. A., Kraut, R. E., & Herbsleb, J. D. (2007), Journal of Management Information Systems, 24(1), p.135-169. 

Coordination is important in software development because it leads to benefits such as cost savings, shorter development cycles, and better-integrated products. Team cognition research suggests that members coordinate through team knowledge, but this perspective has only been investigated in real-time collocated tasks and we know little about which types of team knowledge best help coordination in the most geographically distributed software work. In this field study, we investigate the coordination needs of software teams, how team knowledge affects coordination, and how this effect is influenced by geographic dispersion. Our findings show that software teams have three distinct types of coordination needs—technical, temporal, and process—and that these needs vary with the members' role; geographic distance has a negative effect on coordination, but is mitigated by shared knowledge of the team and presence awareness; and shared task knowledge is more important for coordination among collocated members. We articulate propositions for future research in this area based on our analysis.

"Ambidexterous Coping Strategies in Globally Distributed Software Development Projects", Lee, G., W. DeLone and J. A. Espinosa (2006), Communications of the ACM 49(10): p.35-40. 

Geographic distance, time separation, cultural differences, language differences, organizational boundaries, and functional boundaries inherent in global contexts represent significant barriers for global software teams. A key challenge for information systems organizations today is to overcome these global boundaries and barriers and deliver high-quality software on time and within budget. To shed light on how organizations cope with global boundaries and barriers to succeed in software development, we studied 22 globally distributed software projects. We found that: effective global software teams adopted special coping strategies to handle the difficulties of global contexts and to mitigate their negative effects on project outcomes; global teams tailored task processes and project setups to fit the global context; effective coping strategies used by global software teams exhibited "ambidextrous" properties—i.e., simultaneous rigor and flexibility.

"Global Boundaries, Task Processes and IS Project Success: A Field Study", Espinosa, J. A., G. Lee and W. DeLone (2006), Information, Technology and People 19(4): p.345-370.

The purpose of the paper is to better understand how global boundaries affect global information system (IS) project success and which mediating process variables increase the chance of success. Based on the literature on IS success and global teams, an input-process-output framework is adopted to develop the research model for the study. This research is based on semi-structured interviews with 22 global IS project managers. An attribution analysis is used to identify common themes and patterns of the interview results. Our findings show that global IS project managers identified time separation and cultural differences as the most significant barriers to project success, suggesting that effective teams were able to overcome these barriers to achieve success, but this success was achieved through the implementation of special coordination, communication and cognitive processes tailored to help teams overcome global barriers and through considerable additional cost and effort.

"The Impact of Time Separation on Coordination in Global Software Teams: a Conceptual Foundation", Espinosa, J. A. and E. Carmel (2004), Journal of Software Process: Practice and Improvement 8(4): p.249-266.

While there has been much research on the study of global virtual teams and global software teams, there has been practically no research on the nuances of time separation. We present three converging perspectives on this topic: (1) a view from practices and tactics of global teams; (2) a theoretical view from coordination theories; and (3) a view from our prior research in which we modeled coordination costs for time-separated dyads. Practice suggests that time separation arises not only from time-zone differences, but also from factors such as non-overlapping weekend days and holidays, shifts, and different working schedules. It also suggests that teams employ various coping tactics when faced with time separation – synchronous, asynchronous and education. Theory suggests that communication is necessary to coordinate and that effectiveness of communication is hampered, both in quality and timeliness, when teams are separated by time. Our model, based on coordination theory, suggests that coordination costs contain four main components – communication, clarification, delay, and rework – and that the various aspects of time separated work have different effects on each of these components. Our convergent view from these three perspectives shows: that distance separation is symmetric – i.e., distance (A,B) = distance (B,A) – while time separation is asymmetric, which affects the planning of team interactions; that the timing of activities matters in time separated contexts, but not in contexts with only distance separation; and that *vulnerability costs* (i.e., resolving misunderstandings and re-work) increase with time separation.

"Team Boundary Issues Across Multiple Global Firms", Espinosa, J. A., J. N. Cummings, J. M. Wilson and B. M. Pearce (2003), Journal of Management Information Systems 19(4): p.157-190.

Numerous methodological issues arise when studying teams that span multiple boundaries. The main purpose of this paper is to raise awareness about the challenges of conducting field research on teams in global firms. Based on field research across multiple firms (software development, product development, financial services, and high technology), we outline five types of boundaries that we encountered in our field research (geographical, functional, temporal, identity, and organizational) and discuss methodological issues in distinguishing the effects of one boundary where multiple boundaries exist. We suggest that it is important to: (1)

appropriately measure the boundary of interest to the study, (2) assess and control for other influential boundaries within and across teams, and (3) distinguish the effects of each boundary on each team outcome of interest. Only through careful attention to methodology can we properly assess the effects of team boundaries and appreciate their research and practical implications for designing and using information systems to support collaborative work.

Referred Conference Proceedings

"The Role of Group Cognition in Enterprise Architecting" (best paper nomination), Espinosa, J. A., F. Armour, Boh, W., 44th. Hawaii International Conference on System Sciences, Poipu, Kauai, 2011.

Enterprise architecture (EA) models the desired relationships between business processes and technology. Enterprise "architecting" is the process of developing and maintaining the EA. The goal of EA is to align business process and IT for the effective execution of business strategy and the efficient implementation of the associated systems. Thus, the architecting process involves many stakeholders (e.g., architects, IT staff, and business staff) with very diverse perspectives, making coordination of architecting work daunting. Despite their critical importance to EA success, coordination and governance in EA have received very little attention in the literature. In this paper we report on a study based on semi-structured interviews of CIO's, chief architects, technical architects, IT staff, business stakeholders and EA consultants. The focus of the study was to better understand the coordination challenges and best practices leading to EA success. Our results show that various forms of group cognition play a critical role in the effective coordination of architecting.

"The Organizational Impact of Enterprise Architecture: A Research Framework", Espinosa, J. A., Boh, W., DeLone, W., 44th. Hawaii International Conference on System Sciences, Poipu, Kauai, 2011.

Many organizations have adopted an Enterprise Architecture (EA) approach because of the potential benefits resulting from a more standardized and coordinated approach to systems development and management, and because of the tighter alignment of business and information technology in support of business strategy execution. At the same time, experience shows that having an effective EA practice is easier said than done and the coordination and implementation efforts can be daunting. While nobody disputes the potential benefits of well architected systems, there is no empirical evidence showing whether the organizational benefits of EA outweigh the coordination and management costs associated with the architecting process. Furthermore, most practitioners we have interviewed can provide technical metrics for internal EA efficiency and effectiveness, but none of our participants were able to provide concrete metrics or evidence about the bottom line impact that EA has on the organization as a whole. In this article we raise key issues associated with the evaluation of the organizational impact of EA and propose a framework for empirical research in this area.

"The Main and Interaction Effects of Process Rigor, Process Standardization, and Process Agility on System Performance in Distributed IS Development: An Ambidexterity Perspective",

Lee, G., DeLone, W. H., Espinosa, J. A., International Conference on Information Systems, Saint Louis, MO, 2010.

Information systems (IS) development is becoming increasingly more geographically dispersed. Although process rigor, process standardization, and process agility are generally believed to have a positive impact on software development, it has not been well understood how these process capabilities affect distributed IS development. More important, no prior research has investigated their interaction effects. Drawing upon prior literature on organizational ambidexterity, we hypothesize: positive main effects of process rigor, process standardization, and process agility; a positive interaction effect of process rigor and process agility; and a positive interaction effect of process standardization and process agility on system performance in distributed development. Our data analysis results support a positive main effect of the three process capabilities. We find a positive interaction effect of process rigor and process agility suggesting positive process ambidexterity of rigor and agility. Surprisingly, we find a negative interaction effect of process agility and process standardization suggesting negative process ambidexterity of agility and standardization.

"Coordination in Enterprise Architecting: An Interview Study", Espinosa, J. A., Armour, F., Boh, W. F., 43rd Hawaii International Conference on System Sciences, Kawai, Hawaii, January 2010.

Enterprise architecture (EA) models the desired relationships between business processes and technology. While the conceptual benefits of EA are many, experience shows that managing the EA can be daunting because of the complex interdependencies among business, technology and the people involved. Having sound EA frameworks and programs are necessary but insufficient conditions for EA success. Effective coordination and governance of the EA practice are also necessary, but this has received little attention in the literature. In this paper we begin to fill this gap by providing a reference framework, theoretical foundations and preliminary evidence from semi-structured interviews on coordination and governance in “enterprise architecting.”

"Communication and Performance across Time Zones: A Laboratory Experiment", Nan, N., Espinosa, J. A., Carmel, E., International Conference on Information Systems, Phoenix, Arizona, December 2009.

We often hear that global knowledge work teams are affected by time zone differences, but most research in geographically dispersed collaboration has focused on the effects of distance and has treated time zones as a secondary factor. The experimental study we describe here is part of a larger research program aimed at understanding how technical teams coordinate their work across time zones and which factors influence performance. In this study we investigate how time zone differences affect team performance in a laboratory setting. The study is composed of three phases corresponding to different task type manipulations – simple, complex and equivocal task. In each of the study phases, dyadic teams were randomly assigned into 4 time zone (i.e., work time overlap) conditions: full overlap, 2/3 overlap, 1/3 overlap and no overlap. Teams performed a map drawing task simulating the assembly of software components. We completed data collection for 131 dyad teams. In each phase we collected the following data: team performance (speed and accuracy), exit survey, and chat log capture. In this paper we describe our research design, briefly discuss our preliminary results from analysis of data from Phase 1,

and describe our expectations and next steps for the full study. In Phase 1 we found that time separation has a negative effect on accuracy. We also found that a small amount of time separation has a negative effect on production speed but, surprisingly, speed actually increases with further increases in time separation – a "U" shaped curve. Our chat log text analysis also revealed differences in communication patterns across time zone conditions, which helps explain the unanticipated results. To evaluate if the simplicity of our task influenced our results in Phase 1 we manipulated the task in Phase 2 (added complexity) and Phase 3 (more equivocal). Expected results and implications from these subsequent phases are discussed at the end.

"Process Ambidexterity and Success in Geographically Dispersed Information Systems Development", Lee, G., Espinosa, J. A., DeLone, W. H., Best Paper Proceedings, Academy of Management Conference, Best Paper Proceedings, Chicago, Illinois, August, 2009.

Increasingly more information systems (IS) development teams are geographically distributed in part because of globalization and offshoring trends. However, the increased complexity and dynamics caused by geographic dispersion make it difficult for software teams to coordinate their work and succeed in IS development. Geographically distributed IS development faces two seemingly conflicting requirements. On the one hand, it requires rigor, consistency, formality, discipline, maturity, and alignment in its process to overcome communication and coordination difficulties resulting from team boundaries of distance, time, culture, and organization. On the other hand, distributed development requires agility, flexibility, and adaptability in its process to cope with high uncertainty and dynamism exacerbated by geographic dispersion. We refer to this dual capability as "process ambidexterity" and define it as the IS development capability demonstrating both process alignment and process adaptability. We examine this concept of process ambidexterity and how it affects team coordination effectiveness and success in IS development projects. We also investigate the conditions under which the effects of process alignment and process adaptability on coordination effectiveness are stronger or weaker by examining two important factors that may influence the right balance of process alignment and process adaptability.

"Coordination and Governance in Geographically Distributed Enterprise Architecting: An Empirical Research Design", Espinosa, J. A. and Boh, W. F., Proceedings of the. 42nd. Hawaiian International Conference on System Sciences, Big Island, Hawaii, January, 2009.

Previous research examining the effective implementation and management of enterprise architecture (EA) has typically used a governance perspective. However, this perspective does not consider the challenges associated with the "architecting" effort—i.e., the processes involved in generating and managing the EA. This requires the coordinated action of many stakeholders and architects, especially when they are geographically dispersed because distance and time barriers need to be bridged to coordinate their efforts. In this paper we adapt a previously suggested architecting coordination framework to develop a research model that integrates the coordination and governance perspectives in order to examine the development and implementation of effective geographically dispersed EAs. We use data obtained from two practitioner workshops on EA and follow up interviews with two participants to do some preliminary analysis. We then propose an empirical research design to study our proposed research framework in greater detail.

"Follow the Sun Software Development: New Perspectives, Conceptual Foundation, and Exploratory Field Study", Carmel, E., Dubinsky, Y. and Espinosa, J. A., Proceedings of the. 42nd. Hawaiian International Conference on System Sciences, Big Island, Hawaii, January 2009.

Follow The Sun (FTS) is a special case of global software development. FTS means that software work is handed off every day from one development site to the next -- many time zones away. The main benefit is reduction in development duration. Surprisingly, unlike the broader trend of offshore outsourcing, FTS is practiced rarely and misunderstood often. In this article we present a foundation for understanding FTS including a definition, a description of its place in the life cycle, and choice of methodologies. We also present the outcomes of a first quasi-experiment designed to test FTS and measure the speed of software work. This quasi-experiment is part of our comprehensive research to explore FTS and its implications.

"Distributed Enterprise Architecture: Towards a Theoretical Framework", Espinosa, J. A. and F. Armour, Proceedings of the 41st Hawaiian International Conference on System Sciences, Big Island, Hawaii, January 2008.

Enterprise architecting is becoming critical for most modern organizations whose competitive strategies are tightly linked to the underlying information technology (IT) infrastructure. The reason for this is that enterprise architecture takes a holistic view of the business processes and functions and the information technologies supporting them, rather than the more detailed perspectives provided with application-by-application views. Our understanding of effective enterprise architecting activities is still evolving and this practice is replete with challenges. These challenges are further compounded by the fact that organizations are often geographically dispersed. Furthermore, business processes, technology infrastructure components, information and the people involved may be distributed in different geographic configurations, making it very difficult to comprehend their organization. In this article, we make a first attempt at providing a theoretical framework to guide our thinking for practice and research in this area. We build on the foundations of coordination theory and geographically distributed collaboration research.

"Do Gradations of Time Zone Separation Make a Difference in Performance? A First Laboratory Study", Espinosa, J. A., E. Carmel and N. Nan, International Conference on Global Software Engineering, Munich, Germany. IEEE, August 2007.

We often hear that global software engineering teams are affected by time differences. While there is considerable research on the difficulties of distance, culture and other dimensions, there has been little research that isolated the impact of just time differences. The research question that guides us is whether there are gradual differences across time zones that impact team performance. In this study we conducted a laboratory experiment with 42 dyadic teams. The teams were randomly assigned into 4 time zone overlap conditions: full overlap, 2/3 overlap, 1/3 overlap and no overlap. Using a fictional map task, we found that participants' perceptions of process are unrelated to actual objective performance measures of speed and accuracy. Consistent with our expectations, we found that a small time separation has no effect on

accuracy, but that more time separation has a significant effect on accuracy. Also consistent with our expectations, we found that a small amount of time separation has a significant effect on production speed. However, contrary to our expectations, we found that further increases in partial overlap have less significant effects on speed, and when there is no overlap speed actually increases, albeit not significantly – a "U-shaped" effect.

"Spatial and Temporal Boundaries in Global Teams: Distinguishing Where You Work from When You Work", Cummings, J. N., J. A. Espinosa, and C. Pickering, International Federation for Information Processing (IFIP), Working Group 8.2/9.5. Working Conference on Virtuality and Virtualization. Portland, Oregon, July 2007. 

While spatial boundaries include the geographic differences among team members (e.g., different cities), temporal boundaries include the workday differences among team members (e.g., different time zones). In global teams, members have to deal with both spatial and temporal boundaries, since their co-workers are often located in cities within and across time zones. For global team members with high spatial boundaries and low temporal boundaries (e.g., different cities in the same time zone), synchronous communication technologies such as the telephone and instant messenger provide a means for real-time interaction. However, for global team members with high spatial boundaries and high temporal boundaries (e.g., different cities in different time zones), asynchronous communication technologies such as e-mail and web software provide a way to interact intermittently. Using social network data from 625 team members (representing 5986 pairs) across 137 global teams in a multi-national semiconductor firm, we explore the impact of spatial and temporal boundaries on coordination delay. We also illustrate how member awareness can reduce coordination delay, thus increasing the likelihood of better global team performance.

"Ambidexterity and Global IS Project Success: A Theoretical Model, Lee, G.", W. DeLone and J. A., 40th Hawaiian International Conference on System Sciences, Big Island, Hawaii, January 2007. 

Increasingly more IS projects are globally dispersed. As a result, the success of IS projects can be affected by various global boundaries such as geographical distance, time separation, organizational boundaries and cultural differences. At the same time, system requirements dynamism significantly undermines global IS project performance because it is difficult for global teams to effectively sense and respond to changing system requirements. Therefore, to deliver quality systems on time and within budget in today's dynamic, global environments, process, people, and technology employed by IS projects need to simultaneously exhibit ambidexterity—i.e., both rigor and agility. Drawing upon prior literature and interview data from field studies, this research develops a theoretical model that explains and predicts global IS project success based on ambidextrous project capabilities. Specifically, the model identifies IS project rigor and IS project agility as two key IS project capabilities that moderate the negative effects of global boundary complexity and system requirements dynamism on global IS project success.

"The Effect of Time Separation on Coordination Processes and Outcomes: A Case Study", Espinosa, J. A. and C. Pickering, 39th Hawaiian International Conference on System Sciences, Poipu, Kauai, Hawaii, IEEE, January 2006.

Prior research has discussed and investigated how global teams bridge multiple boundaries (e.g., distance, time, culture) that separate its members and impact the coordination of their work. In this paper we report on a study we conducted at a semiconductor manufacturing company to better understand how global teams can work more effectively across one of these boundaries – time separation. More specifically, we investigate how time zones affect coordination costs and other coordination outcomes, and which coordination processes and mechanism are more effective in helping overcome the difficulties associated with time separation. The study was conducted through semi-structured interviews of 23 global team members working on technical projects in several locations around the globe.

"Coordination Mechanisms in Globally Distributed Software Development", Espinosa, J. A., S. A. Slaughter, J. D. Herbsleb and R. E. Kraut, First International Conference on Management of Globally Distributed Work, Bangalore, India, December 2005.

Despite technological advances in software engineering and collaboration tools, coordination in large-scale, geographically distributed software development continues to be problematic. Traditional theories suggest that collaborators coordinate by programming their tasks and by communicating with each other, but recent research also suggests that they coordinate implicitly through team cognition. However, there is very little empirical evidence on how the use of these various coordination mechanisms affects coordination effectiveness in the context of distributed work. This study investigates coordination in large-scale software development in a major telecommunications firm where the developers are geographically dispersed. Our findings indicate that shared knowledge of team members and use of software configuration management tools are associated with greater coordination effectiveness, while other coordination mechanisms including shared knowledge of the task, general communication, telephone communication and other software tools are not. Further, the use of software configuration management tools has the greatest positive impact on coordination, and developers use the tools not only for task programming but also for communicating about their work. We discuss the implications of our findings for coordination in large-scale, geographically distributed software development.

"Bridging Global Boundaries for IS Project Success", DeLone, W., J. A. Espinosa, G. Lee and E. Carmel, 38th Hawaiian International Conference on System Sciences, Big Island, Hawaii, IEEE, January 2005.

Prior research has discussed and investigated how global teams bridge multiple boundaries (e.g., distance, time, culture) that separate its members and impact the coordination of their work. In this paper we report on a study we conducted at a semiconductor manufacturing company to better understand how global teams can work more effectively across one of these boundaries – time separation. More specifically, we investigate how time zones affect coordination costs and other coordination outcomes, and which coordination processes and mechanism are more effective in helping overcome the difficulties associated with time separation. The study was

conducted through semi-structured interviews of 23 global team members working on technical projects in several locations around the globe.

"The Effect of Time Separation on Coordination Costs in Global Software Teams: A Dyad Model", Espinosa, J. A. and E. Carmel (2004), 37th. Hawaiian International Conference on System Sciences, Big Island, Hawaii, IEEE, January 2004.

Research to date has not addressed the difficulties of coordinating across time zones in global software development. We present a preliminary collaboration model to help us understand the consequences of time separation on coordination costs. The model is for a team composed of dyads and each dyad consists of a task requestor and a task producer who have a sequential workflow dependency. The model is constructed with formulas for: production, coordination, and vulnerability costs for a number of: (1) collaboration modes; (2) time overlap conditions; (3) asynchronous and synchronous communications mechanisms, each of different quality and cost; and (4) production and delay cost rates. We describe the model and evaluate it with regression analysis using randomly generated observations. Our evaluation shows that the model adequately represents time-separated work and that time-separation effects are: (1) different and more complex than distance-separation effects; (2) asymmetric, depending on whether work time overlap between the two actors occurs at the beginning or end of an actor's day; and (3) dependent on the amount of this overlap .

"Modeling Coordination Costs Due to Time Separation in Global Software Teams", Espinosa, J. A. and E. Carmel, Global Software Development Workshop, International Conference on Software Engineering (ICSE), Portland, Oregon, IEEE, May 2003.

Research to date has not attempted to model coordination in global software teams. We formulate a preliminary collaboration model for a dyad to help us understand the consequences of time separation. We first describe the model and its theoretical foundations and we then evaluate the model by simulating several thousand observations and running regression models to inspect the effect of different variables on coordination costs. We then make suggestions for further extension of the model to include more complex scenarios with multiple collaborators and fewer assumptions. Our evaluation shows that the consequences of time separation are complex and that we need to understand them well before we can make claims about coordination outcomes in larger software teams that are separated by time zones.

"Shared Mental Models, Familiarity, and Coordination: A Multi-Method Study of Distributed Software Teams", Espinosa, J. A., R. E. Kraut, S. A. Slaughter, F. J. Lerch, J. D. Herbsleb and A. Mockus, International Conference in Information Systems, Barcelona, Spain, December 2002.

Coordination is important in large-scale software development because of the many people involved and the complex dependencies present in software tasks. Even small improvements in productivity can lead to substantial cost savings and competitive advantage. But despite great technological advances in software engineering and collaboration tools in recent years, coordination in software development projects continues to be problematic. Traditional theories suggest that team members coordinate through task programming mechanisms and by

communicating with each other, but more recent research also suggests that they coordinate through work familiarity, and team cognition mechanisms like shared mental models. This paper reports on the results of a multi-method research investigation of how shared mental models, work familiarity and geographic dispersion affect coordination in software teams. This research is based on three studies conducted at a large telecommunications company: face-to-face interviews, survey, and archival studies. Results show that shared mental models have a positive effect on team coordination and that prior familiarity with the same software parts and projects reduces software development time. Results also indicate that geographic dispersion increases software development time and that the effect of work familiarity is stronger for geographically distributed teams than for co-located teams.

"Research on Teams with Multiple Boundaries", Espinosa, J. A., J. N. Cummings, B. M. Pearce and J. M. Wilson, 35th Hawaiian International Conference on System Sciences, Big Island, Hawaii, IEEE, January 2002.

The main purpose of this paper is to discuss: (a) types of boundaries found in field research on teams; (b) methodological challenges encountered when examining teams that cross boundaries; and (c) possible research design solutions. Based on our own field research at three companies (a software development organization, a telecommunications firm, and a financial institution), we outline four different types of boundaries (geographical, functional, identity, and organizational) and discuss methodological issues in distinguishing the effects of one boundary where multiple boundaries existed. We suggest solutions to help: (a) isolate the effects of distance, (b) assess functional similarities within and across teams, (c) identify and control for the impact of multiple project affiliations, and (d) distinguish organizational level influences. Only through careful attention to measurement can we properly assess the effects of team boundaries and draw accurate conclusions about these changing forms of organizing.

"Shared Mental Models and Coordination in Large-Scale, Distributed Software Development", Espinosa, J. A., R. E. Kraut, F. J. Lerch, S. A. Slaughter, J. D. Herbsleb and A. Mockus, International Conference in Information Systems, New Orleans, Louisiana, December 2001.

Despite substantial improvements in the last few years in software engineering and collaboration tools, coordination in large-scale software development continues to be problematic. This coordination is important because of the complex interdependencies that exist among software tasks, in that small productivity improvements can lead to substantial cost-savings and competitiveness. Traditional theories suggest that collaborators coordinate by organizing tasks and communicating, but recent research suggests that they also coordinate via implicit mechanisms like shared mental models. However, most of the shared mental model research literature focuses on real-time tasks, and there is very little empirical evidence on how these models affect coordination in more asynchronous and geographically distributed collaboration. Furthermore, none of this evidence is based on large-scale software development organizations. The present research is a field study at a large telecommunications company. It employs qualitative, quantitative, and survey research methods to investigate the effect of shared mental models on coordination in large-scale software development and to better understand how geographic distance affects coordination.

"Shared Mental Models: Accuracy and Visual Representation", Espinosa, J. A., Americas Conference in Information Systems, Boston MA, Association for Information Systems, August 2001.

Teams are important for organizational work but coordinating teamwork is not always easy. Oftentimes members are separated by time or geographic distance, thus making coordination even more difficult. Recent research suggests that teams develop shared mental models about the task and each other, which helps them develop mutual explanations and expectations about the task environment, thus helping its members coordinate implicitly. The theoretical grounding of this research literature is strong, and recent evidence is beginning to provide some support for it. But in order to make good progress in this area we need to develop and validate shared mental model measures that can be used across studies. In this study we build upon methodological contributions on shared mental model measurement and propose, describe, and empirically validate a measure for shared mental model accuracy using network analysis methods. We also use the resulting network data to illustrate the visual representation of shared mental models and their accuracy.

"Coming to the Wrong Decision Quickly: Why Awareness Tools Must be Matched with Appropriate Tasks", Espinosa, J. A., J. Cadiz, L. Rico-Gutierrez, R. E. Kraut, W. Scherlis and G. Lautenbacher, Computer-Human Interaction (CHI), Association of the Computer Machinery's (ACM), The Hague, The Netherlands, ACM Press, March 2000.

This paper presents an awareness tool designed to help distributed, asynchronous groups solve problems quickly. Using a lab study, it was found that groups that used the awareness tool tended to converge and agree upon a solution more quickly. However, it was also found that individuals who did not use the awareness tool got closer to the correct solution. Implications for the design of awareness tools are discussed, with particular attention paid to the importance of matching the features of an awareness tool with a workgroup's tasks and goals.

Selected Referred Conference Articles without Proceedings

"Coordination Complexity in Geographically Distributed Collaboration", Espinosa, J. A. and R. Verburg, symposium co-chairs and co-organizers, including paper "Virtual Team Boundary Complexity: A Team Coordination Perspective", J. A. Espinosa, G. Lee and W. DeLone, Academy of Management Conference, Philadelphia, Pennsylvania, August 2007

"Your Time Zone or Mine? Geographic Configurations, Global Team Coordination, and Project Outcomes", Espinosa, J. A., J. N. Cummings and C. Pickering, Academy of Management Conference, Atlanta, Georgia, August 2006.

A team's configuration across distance and time can affect the coordination challenges its members need to overcome to get the job done. However, the effects of geographic distance and time separation are often confounded in global teams' research. In this paper we report on a survey study of 71 teams in a semiconductor manufacturing company to investigate how various distance and time configuration variables influence team coordination processes and outcomes. Our results show that the team's geographic configuration is associated with coordination

processes, coordination outcomes and project performance and impact. Interestingly, these associations are observed with different geographic configuration variables. For example, the geographic distance only affects team communication and team knowledge. However, the number of time zones represented in a project is associated with longer communication delays, but it does not affect other process variables or coordination problems directly. But communication delay is positively associated with coordination problems. On the other hand, the maximum time zone spanned in a team is negatively associated with coordination problems, project performance and project impact. Teams with better task organization exhibited fewer coordination problems but, interestingly, none of the geographic configuration variables had an association with the use of task organization mechanisms.

"Coordination in Global Teams: A Framework for Exploration", Espinosa, J. A. and M. A. Clark, Academy of Management Conference, Atlanta, Georgia, August 2006.

We offer an inclusive framework for studying coordination in global teams, focusing on the management of task dependencies by considering theoretical perspectives from the virtual teams, team cognition, global management, and coordination research literatures. Coordination processes (mechanistic and organic) are presented as the heart of an input-process-output (IPO) model, preceded by situational inputs (characteristics of the task and work context) and leading to coordination states (effectiveness and cost) and ultimately to performance outcomes.

"Structuring Team Knowledge: Dimensions, Beliefs, Distribution, & Coordination", Espinosa, J. A. and M. A. Clark, symposium co-chairs and organizers, including symposium paper "Structural Dimensions of Team Knowledge", Clark, M. A. and J. A. Espinosa, Academy of Management Conference, Oahu, Hawaii, August 2005.

Understanding the structure of knowledge employed by organizational teams – how it is held, processed, or formatted for use – is crucial in fulfilling their promise for today's organizations. While many have proposed dimensions of knowledge, much of the work in this area has described the content of the knowledge (e.g., the domain and its measure), and therefore has not sufficiently accounted for the additional process concerns, such as coordination, directory systems, and distribution of knowledge. The presenters in this symposium offer several perspectives to inform and extend the structural conceptualization of team knowledge, including methodological considerations and connections to team performance outcomes. First, "Network Structure & Expertise Coordination in Knowledge Teams" discusses the coordination of specific expertise structures – networks of technical, design, and domain experts – and their effect on team performance. Next, "Knowledge, Ignorance, & Distortion: An Expanded Representation of Belief Structures in Groups" discusses the structure of belief within a team context, contrasting knowledge that is relevant in completing a given team task with other beliefs that teams may have (distortion) or lack (ignorance) in relation to the task. "Transactive Memory: Measuring Knowledge Distribution & Effectiveness" decomposes transactive memory into "sharedness," "accuracy," and "validation" dimensions. Finally, "Structural Dimensions of Team Knowledge" organizes these and other views of team knowledge into six key structural dimensions used in extant team knowledge research: sharedness, externalization, maturity, distribution, time-span, and tacit versus explicit. Together, these perspectives inform the domain of acceptable measures of team knowledge and advance understanding of its forms.

"A New Vision of Team Knowledge: Multidimensional Content and Structure", Clark, M. A. and J. Al. Espinosa, Academy of Management Conference, Oahu, Hawaii, August 2005.

"Identifying New Directions in Group Research" with Carnegie Mellon faculty: S. Slaughter, R. Kraut, L. Argote, L. Weingart, S. Kiesler and P. Goodman, panel symposium at the Academy of Management conference, New Orleans, Luisiana, December 2004.

"Individual, Group and Organizational Learning in Software Development: A Learning Curve Analysis", Boh, W. and S. A. Slaughter and J. A. Espinosa, Academy of Management Conference, Seattle , Washington, August 2003 [See journal article above].

"The Effect of Task Knowledge Similarity and Distribution on Asynchronous Team Coordination and Performance: Empirical Evidence from Decision Teams", with Carley, K., Kraut, R. E., Slaughter, S. A., Lerch, F. J. and Fussell, S., Second Information Systems Cognitive Research Exchange (IS CoRE) workshop, Barcelona, Spain, 2002.

There is agreement in the literature, but little empirical evidence, that team mental models positively influence team coordination and performance. However, most of the empirical evidence on the effects of team mental models are from teams working on real-time (i.e., synchronous) tasks and, to the best of our knowledge, none of the prior studies have taken into account task knowledge distribution within teams. However, most organizational teams work asynchronously (i.e., not always at the same time) and task knowledge distribution varies within teams. Consequently, this study proposes a framework for the study of the effect of team mental models on coordination, and uses this framework to more specifically investigate how two aspects aspect of the team mental model construct—i.e., task knowledge similarity and distribution of task knowledge—influence team coordination and performance. Using data from decision teams, our results suggest that task knowledge similarity has a positive effect on activity coordination and strategy coordination, and that the leader's task knowledge centrality has a positive effect on strategy coordination. Strategy coordination, in turn, is associated with superior team performance, both in terms of objective financial performance and external board evaluations.

Book Chapters

"Coordination in Global Teams", M. A. Clark and J. A. Espinosa, in "Handbook of 21st. Century Management," Wankel, C. (Ed.), 2008, Sage, ISBN 978-1-4129-4972-9..

Multinational organizations increasingly accomplish their work through teams that span both local and global boundaries – functions, identity, organizational borders, geographic distance, temporal distance, and culture. Global team performance largely depends on their effectiveness in selecting an appropriate mix of coordination processes – mechanistic, organic, or cognitive – that bridge the particular boundaries present in their teams.

"Explicit vs. Implicit Coordination Mechanisms and Task Dependencies: One Size Does Not Fit All.", with Lerch, F. J. and Kraut, R. E. (2004), in E. Salas and S. M. Fiore (Eds.), Team Cognition: Process and Performance at the Inter- and Intra-individual Level, p. 107-129, ch. 6,

2004, peer reviewed and published by the American Psychological Association, Washington, DC, ISBN 1-59147-103-6.

In this chapter we formulate and discuss a unified framework of team coordination that incorporates both explicit and implicit coordination mechanisms. We also discuss the importance of identifying key dependencies and coordination types for a given task and we present examples and results from our empirical studies with: (1) decision teams who managed virtual companies in a Management Game simulation and large-scale, geographically distributed software development teams from a Fortune 500 telecommunications company.