JOURNAL OF INFORMATION TECHNOLOGY THEORY AND APPLICATION

ISSN: 1532-3416

Understanding Coordination in the Information Systems Domain: Conceptualization and Implications

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Abstract:

In this paper, we suggest a new conceptualization of coordination in the information systems (IS) domain. The conceptualization builds on neurobiological predispositions for coordinating actions. We assume that human evolution has led to the development of a neurobiological substrate that enables individuals to coordinate everyday actions. At heart, we discuss six activity modalities: contextualization, objectivation, spatialization, temporalization, stabilization, and transition. Specifically, we discuss that these modalities need to collectively function for successful coordination. To illustrate as much, we apply our conceptualization to important IS research areas, including project management and interface design. Generally, our new conceptualization holds value for coordination research on all four levels of analysis that we identified based on reviewing the IS literature (i.e., group, intra-organization, inter-organization, and IT artifact). In this way, our new approach, grounded in neurobiological findings, provides a high-level theory to explain coordination success or coordination failure and, hence, is independent from a specific level of analysis. From a practitioner's perspective, the conceptualization provides a guideline for designing organizational interventions and IT artifacts. Because social initiatives are essential in multiple IS domains (e.g., software development, implementation of enterprise systems) and because the design of collaborative software tools is an important IS topic, this paper contributes to a fundamental phenomenon in the IS domain and does so from a new conceptual perspective.

Keywords: Activity Modalities, Brain, Cognitive Neuroscience, Coordination, Evolution, Neurobiology, NeuroIS, Neuroscience, Information Systems, Collaborative Software, Project Management.

Jan vom Brocke acted as the Senior Editor for this paper.

"I do not see any way to avoid the problem of coordination and still understand the physical basis of life."

—Howard Pattee (1976, p. 176)

1 Introduction

Coordination is at the core of human existence. People have to coordinate their actions to survive. Individuals must be able to coordinate their actions both individually (e.g., moving their arms and legs in a harmonious way) and socially (e.g., through gestures or speech). Without coordination on both the individual and social level, humans may not have survived for the past millions of years. Importantly, without coordination, collective achievements in human society would not have been possible, which includes works such as the Egyptian pyramids and more abstract accomplishments such as Wikipedia.

Coordination is also a central purpose in organizations (Barki & Pinsonneault, 2005, Faraj & Xiao, 2006, Okhuysen & Bechky, 2009). To effectively fulfill organizational objectives, organizational members need to coordinate their activities, and, today, software tools usually support this coordination (Marjanovic 2005). Hence, coordination is an important research topic not only in organization science but also in several other scientific disciplines including information systems (IS). While scholars have developed numerous definitions during the past several decades in different scientific disciplines (e.g., Larsson (1990) lists 19 definitions; see also Malone & Crowston (1994)), the essence of the concept is intuitively clear in most people's minds. As it pertains to the individual level, Merriam Webster Dictionary defines coordination as "the ability to move different parts of [the] body together well or easily"; as it pertains to the social level, the same source defines that coordination is "the process of organizing people or groups so that they work together properly and well" ("coordination", n.d.). Etymologically, the term originates from Late Latin *coordinare* ("to set in order, arrange").

However, while these definitions capture the essence of the concept well, they do not shed light on the concept's nature and dimensionality. In short, as Grant (1996) expresses, "organization theory lacks a rigorous, integrated, well developed, and widely agreed theory of coordination" (p. 113). This theoretical paucity is problematic because, without such a knowledge base, it is difficult to understand the antecedents and consequences of coordination in depth. Moreover, such a theoretical gap impedes the development of effective organizational interventions, including IT artifacts such as collaborative software. Thus, while one can often easily diagnose an organization with coordination problems (e.g., in IT projects that do not meet planned deadlines, costs, and/or quality requirements), one can often not so easily identify and understand the root causes of the problem, which renders the development of effective solutions difficult or even impossible.

In contrast to extant approaches (see Section 2), the conceptualization we suggest originates from the simple fact that humans are endowed with certain capabilities for coordinating everyday actions, such as walking or communicating, and humans also employ the same capabilities when coordinating tasks in social settings (e.g., interaction among individuals in organizations). This new conceptualization implies that we take a neurobiological perspective on coordination. As a result of random mutations in human genetic makeup that occurred during ancient epochs of human history (starting from the time of the emergence of early hominids such as Australopithecus afarensis some 3.5 million years ago), some individuals developed better coordination abilities than others. Because better coordination performance increases chances for survival, those genetic mutations supporting coordination were then passed on to offspring until the mutations became established as species-wide traits. As such, applying Darwin's theory of evolution (Darwin, 1859) suggests that modern humans are endowed with a neurobiological substrate that enables them to coordinate everyday actions related to both the individual level (e.g., walking, grasping, using tools) and the social level (e.g., communication with other humans, understanding other people's intentions)[1]. While this neurobiological substrate includes components of the entire human nervous system (i.e., central and peripheral), its major part is the brain and, hence, our focus in this paper.

[1] With respect to coordination of motor movements (e.g., hand motor skills), evidence indicates that such coordinative skills are significantly heritable (Francks et al., 2003). In a related stream of research, Segal, McGuire, Miller, and Havlena (2008) conducted a study to determine if tacit coordination (defined as non-negotiated consensus) varies as a function of genetic relatedness between social actors. The sample included monozygotic (MZ) twin pairs, dizygotic (DZ) twin pairs, and virtual twin pairs (i.e., same-age unrelated siblings); note that MZ twins share the same genes, whereas the genes of DZ twins are only imperfectly correlated. Intriguingly, MZ twins showed significantly greater overall agreement in a social coordination questionnaire than DZ twins and virtual

Consequently, every healthy human being is born with certain capabilities that enable coordination and that need to be fully developed into coordinative abilities after birth during ontogeny. These abilities will differ according to whatever situation the individual encounters. Thus, while human coordinative capabilities have a genetic basis, variance in those capabilities always results from the complex interplay between both biological and environmental factors (e.g., Cacioppo, Bernston, Sheridan, & McClintock, 2000), including tools and symbols. As such, the properties of the internal functional space in the brain made up of neurons and their connections need somehow to be homomorphic with the properties of the external world (Llinás, 2001, p. 65). A major reason for this homomorphism is that the functional organization of the brain has evolved in interaction with the environment to secure the survival of the human species (e.g., Buss, 1999; Cartwright, 2000). Thus, what is "internal" and what is "external" cannot be independent from each other[2].

How one should conceptualize the homomorphism remains a crucial issue. As a result of long-term scientific investigations into the success potential of coordination in large projects in the telecom industry, Taxén devised the concept of activity modalities (Taxén 2003, 2009, 2011, 2012)[3]. These modalities (contextualization, objectivation, spatialization, temporalization, stabilization, and transition) denote interdependent capacities in the neurobiological substrate that are imperative for coordination. For example, spatialization describes the capacity of spatial orientation. Damage in the hippocampus, a region deeply located in the brain's temporal lobe, may severely impair spatial navigation abilities and, thereby, impede orientation towards a desired target (Posner & Petersen, 1990), which may negatively affect coordination abilities. Based on this kind of reasoning, we argue that humans are inescapably bound to the constraints and possibilities of their biological constitution when coordinating actions, which means that the activity modalities inevitably come into effect in every coordinative situation, including those in which information systems are used to support coordination (e.g., collaborative tools). Thus, if information systems, along with other organizational interventions, are designed to support the activity modalities, we can expect their coordinative abilities to be high and, thereby, contribute to organizational efficiency. We base our paper on this rationale.

Contribution:

This paper provides a high-level theory to explain coordination success or failure. This new conceptualization of coordination builds on neurobiological predispositions for coordinating actions. We describe six activity modalities (contextualization, objectivation, spatialization, temporalization, stabilization, and transition) and show that the collective functioning of these modalities is essential for successful coordination. We demonstrate the utility of our theory based on concrete applications, including project management and interface design. From a research perspective, this new conceptualization complements earlier theories by providing a novel perspective on coordination. From a practitioner's perspective, the conceptualization provides a guideline for designing organizational interventions and IT artifacts. Since social initiatives and collaborative software tools are important in multiple IS domains, this paper contributes to a fundamental phenomenon in information systems theory and practice.

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twins. This result strongly supports the notion that not only do motor coordination skills have a genetic basis but also that coordination skills in social settings might have a genetic foundation.

[2] As an example, visual perception in the human brain is related to activity in different cortical areas, each of which has specialized to some degree in processing specific attributes of the stimulus. Specifically, once processing of visual information has taken place in the retina, the optic nerve transmits information into the brain. The primary visual cortex (also referred to as striate cortex or V1) processes spatial information (among other attributes) and modulates attention; moreover, cells in V2 (shape processing), V3 (global motion processing), V4 (color processing), V5 (processing of speed and direction of the moving stimulus), and V6 (distinguishing object and self-motion) serve highly specialized functions in visual perception (e.g., Gazzaniga, Ivry, & Mangun, 2009, pp. 177-198), which supports the notion of homomorphism between the internal and external realms. Intriguingly, evidence shows that there are even cells in the human brain (the fusiform face area) specialized in the processing of faces (Kanwisher, McDermott, & Chun, 1997). In this context, Baars and Gage (2010, p. 169, emphasis in original), in their seminal book on cognition, brain, and consciousness, write that "[s]ome of these *face cells* show remarkable precision in what they respond to and might respond best to a face of a particular identity, facial expression, or to a particular viewpoint of a face". Obviously, the more nerve cells are specialized in processing specific kinds of external stimulus information, the higher the degree of homomorphism between the external and internal realms.

[3] Taxen (2003) describes the research design we used to conceptualize the activity modalities.

In summary, we argue that 1) the phylogenetic evolution of mankind has endowed humans with certain capabilities for coordinating actions; 2) depending on the specific circumstances which an individual encounters, the development of an individual's capabilities into coordinative abilities manifests in different ways; 3) the neurobiological substrate of coordination includes capacities that we refer to as activity modalities, and these modalities are necessary, albeit not necessarily sufficient, for the successful coordination of actions; 4) when coordinating actions, humans employ extracortical means such as tools, instruments, and language (among other things) to sustain and enhance coordination; and 5) collaborative software tools are one such class of means. If one designs these tools in conjunction with the activity modalities, we can expect to enhance coordination in organizations.

To develop this rationale and illustrate its potential for IS theorizing and artifact design, we structure the paper into a theoretical and an applied part. First, however, we discuss related work on coordination in the IS field in Section 2. The theoretical part of the paper comprises Sections 3 to 4. In Section 3, we introduce the six activity modalities with the aid of a mammoth hunt example. The idea behind illustrating the activity modalities using a historical activity is to convey the fact that the underlying structure of coordination is the same in every activity, largely independent of time and place, and that it has developed during human evolution. Moreover, the example emphasizes that the nature of the neurobiological substrate has not changed much, if at all, since the dawn of mankind. Subsequently, in Section 4, we discuss the neurobiological substrate of the activity modalities. Specifically, we argue that humans have specialized circuits in the brain that contribute to realizing the six activity modalities. The applied part of the paper comprises Sections 5 and 6. In Section 5, we outline exemplary IS research domains in which our conceptualization holds significant potential to develop a better understanding of real-world phenomena. We propose that one may use the conceptualization as a theoretical lens to better understand success and failures of IT projects and to develop insight into user satisfaction with, and acceptance of, collaborative software. Furthermore, in Section 6, we show that one may use the conceptualization as a practical guideline for designing organizational interventions and IT artifacts. In Section 7, we outline the paper's limitations and describe potential avenues for future research. Finally, in Section 8, we conclude the paper.

2 Related Work

Researchers made major contributions to coordination research in organization science and sociology long before the topic started to emerge in the IS discipline. In seminal publications, March and Simon (1958), Thompson (1967), and Van de Ven, Delbecq, and Koenig (1976) presented frameworks that, in essence, indicate that coordination may be based on pre-established routines and procedures (referred to as "mechanistic coordination" or "coordination by plan") or situational communication among team members (referred to as "organic coordination" or "coordination by feedback"). Generally, mechanistic coordination is more effective than organic coordination in stable environments where tasks are highly predictable and routine. However, with the environment's increasing instability, tasks become less predictable and routine, and, hence, organic coordination becomes a more effective coordination mode in such environments.

Malone and Crowston (1990, 1994) also laid a major foundation for the development of research on coordination in the IS discipline. In essence, they describe a framework for a coordination theory from an interdisciplinary viewpoint and outline application domains of the framework in IS areas, including the design of collaborative software and the fundamental question of how IT may change coordination in and across organizational boundaries. While we cannot comprehensively review Malone and Crowston's work here, we highlight some major contributions that 1) have noticeably influenced work on coordination in the IS discipline and 2) hold significant value for coordination in practice (e.g., in project management or for the design of groupware systems).

Malone and Crowston (1990) developed two definitions of coordination, a broad one ("the act of working together harmoniously" (p. 358)) and a more narrow one ("the act of managing interdependencies between activities performed to achieve a goal" (p. 361)). Moreover, in their effort to develop a framework for a coordination theory, they decompose coordination into four components and assign specific coordination processes to each component. Specifically, they indicate the following components and associated processes: 1) goals (identifying goals), 2) activities (mapping goals to activities, including goal decomposition), 3) actors (selecting actors and assigning activities to actors), and 4) interdependencies (managing interdependencies among the components). With respect to the fourth component, they extensively elaborate on different kinds of dependencies. As an example, one major kind of dependency is shared resources, and a manager's "first come/first serve" or situational decisions (among others) are examples of coordination processes for handling this specific dependency (Malone & Crowston 1994, p. 91). Importantly, Malone and Crowston (1990, 1994) discuss a comprehensive list of different kinds of dependencies along with corresponding management processes, all of which are crucial in IS project management initiatives (e.g., enterprise resource planning, outsourcing, or software development). Also, they discuss further processes important for successful coordination, such as group decision making or communication. Finally, Malone and Crowston (1990, 1994) highlight that a coordination theory, including their own framework, holds significant value for the management of intra- and inter-organizational initiatives and the design of collaborative-work tools (among other things). We use these two domains to demonstrate the value of our new approach (see Section 6).

Since the late 1980s, mainstream IS journals have published a vast number of papers with an explicit focus on coordination[4]. We analyzed these studies to develop a "big picture" view on the IS coordination literature[5]. Generally, our analysis revealed that coordination has been an important research topic in the IS discipline, a fact that meta-research in the IS discipline has also confirmed (see Sidorova, Evangelopoulus, Valacich, & Ramakrishnan, 2008; Steininger, Riedl, Roithmayr, & Mertens, 2009). Altogether, we identified 40 papers with an explicit focus on coordination in the Senior Scholars' basket of eight journals[6]. Also, we found that the IS coordination literature was not very homogeneous predominantly because the studies refer to different levels of analysis (see Table 1 and a brief description in the next paragraph) and, hence, use different conceptual foundations. Against the background of this heterogeneity, a cumulative research tradition is difficult to establish.

We grouped the 40 papers into four categories (levels of analysis): 1) group (e.g., software development teams), 2) firm (intra-organization) (e.g., business process management across functional units in an organization or IT governance), 3) firm (inter-organization) (e.g., supply chain management or contracts between customers and clients in outsourcing relationships), and 4) IT artifact (e.g., design of features of groupware systems). Our classification (Table 1) shows that research pertaining to the group level dominated (16 papers), followed by research pertaining to the inter-organization (13 papers), intra-organization (9 papers), and IT artifact levels (2 papers). Moreover, we found that coordination in software engineering was the most intensively studied single topic in the IS coordination literature[7].

As Table 1 indicates, we also analyzed the research methods used in the extant IS coordination literature. While different methods have been used with different frequencies, a general observation is that scholars have applied both quantitative (i.e., survey (8 papers), laboratory experiment (7), mathematical modelling and simulation experiments (5)) and qualitative methods (i.e., case study (10), interview (5), action research (1), content analysis (1)) to a considerable degree to study coordination in the IS domain (note that three papers are conceptual in nature).

[4] The first paper we could identify in a basket of eight journal with an explicit focus on coordination was Lederer and Mendelow (1989).
[5] A search on August 23, 2014, via Web of Science™ (terms: "coordination" and "coordinating"; search in paper title; condition: publication name: "European Journal of Information Systems", "Information Systems Journal", "Information Systems Research", "Journal of the Association for Information Systems", "Journal of Information Technology", "Journal of Management Information Systems", "Journal of Strategic Information Systems", "MIS Quarterly"); no time restriction) resulted in 40 hits: *EJIS* (5), *ISJ* (1), *ISR* (10), *JAIS* (2), *JIT* (4), *JMIS* (15), J*SIS* (1), *MISQ* (2) (note that we did not consider papers such as editorials in this list). Table 1 lists the 40 papers.
[6] For details, please see http://aisnet.org/?SeniorScholarBasket.
[7] Generally, while we believe that one should be cautious in generalizing our literature review results to the IS discipline as a whole (because our analysis focused on the Senior Scholars' basket of eight journals), we believe that the findings of our analysis well reflect the research status of the IS literature on coordination.

Table 1. IS Literature with Explicit Focus on Coordination from the Senior Scholars' Basket of Eight Journals

Paper and topic	Description of study and major results	Research method
Group level		
JAIS		
Chua & Yeow (2010) Cross-project coordination in open-source communities	The materiality of development artefacts influence ongoing cross-project ordering systems (i.e., unique combinations of coordination artefacts and practices arising from organizational needs to manage interdependencies that transcend local interactions to produce a workable degree of order). Also, affordances that emerge from the interaction between the goals and desires of the project team and the materiality of the development artefact influence the emergent trajectory of cross-project ordering systems.	Case study (N = 4), different projects performed on the open source game Jagged Alliance 2 in the forum Bear's Pit
Lowry, Roberts, Dean, & Marakas (2009) Implicit coordination in usability evaluation	Usability flaws identified in the later stages of a software development process are usually costly to resolve. Hence, usability evaluation is a crucial part in software engineering processes. The study examined how the inexpensive method of heuristic evaluation can benefit from collaborative software, implicit coordination, and principles from collaboration engineering. The study defines implicit coordination as unspoken and understood coordination that occurs with increased familiarity with a task and a group, resulting in group knowledge. Results indicate that groups can experience implicit coordination through the collaborative software features of group memory and group awareness.	Laboratory experiment (N = 417) with students who were organized in 107 groups
ISR		
Cummings, Espinosa, & Pickering (2009) Spatial and temporal boundaries in globally distributed projects	In globally distributed projects, members have to deal with spatial boundaries (different cities) and temporal boundaries (different work hours due to time zone differences). While synchronous communication technologies (e.g., telephone, instant messaging, and videoconferencing) can be used for interaction for members with spatial boundaries but no temporal boundaries, for members with spatial and temporal boundaries (those in different cities with nonoverlapping work hours), asynchronous communication technologies (e.g., email) have to be used. The authors report that the likelihood of delay (i.e., time lag in resolving issues, clarifying communication, and reworking tasks) for pairs of members is a function of the spatial and temporal boundaries that separate them and the communication technologies they use to coordinate their work.	Interviews (N = 23) with technical project members, followed by a survey (N = 675) of managers across 108 projects in a multinational semiconductor firm
Dabbish & Kraut (2008) Design of awareness displays in collaborative software tools	Awareness displays provide contextual information about the activities of group members. The authors investigated the conditions under which awareness displays improve coordination and the types of designs that most effectively support communication timing. Awareness displays containing information about a remote collaborator's workload result in communication attempts that were less disruptive but only when the interrupter had incentives to be concerned about the collaborator's welfare. Also, high-information awareness displays harmed interrupters' task performance while abstract displays did not.	Laboratory experiment study 1 (behavioural): N = 72 students (36 pairs) Study 2 (behavioural and eye-tracking): N = 66 students (33 pairs)
Koushik & Mookerjee (1995) Coordination in software development	In software development, the individual efforts of the programmers need to be coordinated to ensure product quality and the team's effectiveness. In this study, the authors modeled the process of coordination in the construction phase of incrementally developed, modular software systems. The model supports decisions about team size and coordination policy. Moreover, the authors used the results from the model to investigate the nature of coordination in software development; they found that more complex systems needed a higher level of coordination than simpler ones, and, if the time available for construction is reduced, it was optimal to reduce the level of coordination.	Mathematical modelling and simulation experiments

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Ramesh & Whinston (1994) Formalisms for Coordination	Organizational decisions arise out of a combination of formal analyses and less formal interactions among decision makers. The authors analyzed the pragmatics of group decision processes from the perspective of argumentation. Specifically, they develop formalisms for representing argumentative knowledge, gaming the argumentation process, and coordinating games. The representation formalism provides a framework for organizing the logic underlying the claims and arguments in a group. The gaming formalism provides a framework for conducting and regulating the group interactions. The framework may constitute the basis for designing computer-assisted systems that support argumentation processes in groups.	Mathematical modelling
	JMIS	
Andres & Zmud (2001) Software development coordination	Projects characterized by low task interdependence exhibited greater productivity than projects with high task interdependence. Organic coordination (i.e., informal communication, cooperative climate, and decentralized decision making) was more productive than mechanistic coordination (i.e., formal communication, strong controlling, and centralized decision making).	Laboratory experiment (N = 80) with student sample
Espinosa, Slaughter, Kraut, & Herbsleb (2007) Team knowledge and coordination in geographically distributed software development	Team cognition research suggests that software developers coordinate through team knowledge, but this perspective has hardly been explored in geographically distributed software development initiatives. The study reports on the coordination needs of software teams, how team knowledge affects coordination, and how geographic dispersion influences this effect. Results indicate that software teams have three types of coordination needs (technical, temporal, and process) and that these needs vary with the members' role in the project. Moreover, the authors found that geographic distance had a negative effect on coordination but was mitigated by the team's shared knowledge and presence awareness.	Case study (N = 1) of a large telecommunications firm that develops software for wireless networks in Europe
Fritz, Narasimhan, & Hyeun-Suk (1998) Communication and coordination in virtual offices	IT has changed traditional work practices and managerial strategies. In particular, traditional office communication with with co-workers, which is often dependent on physical proximity, has changed. The authors examined the influence of organizational factors (i.e., job characteristics, IT support, and coordination methods) on satisfaction with office communication in two work environments (i.e., face-to-face vs. IT-based) was. Satisfaction with office communication was higher in the IT-based environment.	Survey (N = 230) of individuals in nine firms in the Atlanta area
Horton & Biolsi (1993) Coordination challenges in computer-supported collaborative work	The authors examined the nature of computer-supported collaborative work. Based on a distinction between well-coordinated and poorly coordinated groups, they studied several outcome variables. Results indicate that well-coordinated groups tended to evaluate groupware tools more favourably in terms of both current and future usefulness. Moreover, individuals in the well-coordinated groups were more positive about task performance than those in the poorly coordinated groups. Moreover, satisfaction with group work was also rated higher in the well-coordinated groups. However, the effectiveness of coordination had little bearing on output quality (here written documents whose quality experts assessed).	Laboratory experiment (sample size not directly specified: six groups of students, and groups ranged in size from 4-5 members)
Massey, Montoya-Weiss, & Hung (2003) Temporal coordination in global virtual project teams	The authors examined the nature of team interaction and the role of temporal coordination in asynchronously communicating global virtual project teams. They identified distinct patterns of interaction and explored how these patterns are related to differential levels of team performance. Moreover, findings show that successful enactment of temporal coordination mechanisms was associated with higher performance.	Laboratory experiment (N = 175) with students in 35 groups (i.e., 5 person teams); 34 Japanese students and 141 American students

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Ren, Kiesler, & Fussell (2008) Multiple group coordination in complex and dynamic task environments	Collaboration in complex and dynamic environments (e.g., in hospitals) is challenging. Coordination performance is affected by coordination quality across different stakeholders (e.g., physicians, nurses, or patients) whose incentives, cultures, and routines can conflict. The authors investigated coordination practices in the context of a hospital's operating room. They studied workflow across groups and critical events when coordination had broken down. Analysis of the sources, coping mechanisms, and consequences of coordination breakdowns revealed three factors important to deal with unexpected breakdowns: 1) trajectory awareness of what is going on beyond an individual's immediate workspace, 2) IT systems integration, and 3) information pooling and learning at the organizational level.	Case study (N = 1) of a hospital in an urban setting in the US
	EJIS	
Gosain, Lee, & Kim (2005) Management of cross-functional inter-dependencies in ERP implementations	The authors investigated cross-functional coordination in enterprise resource planning (ERP) projects. They identified three major patterns of managing functional inter-dependencies: 1) a lean coordination pattern that involves intricately planned "vanilla" implementations using reference process models, 2) a rich coordination pattern based on managing inter-dependencies through organizing arrangements and cultural interventions, and 3) a mediation pattern based on executive mandate or a dominant functional unit laying out the rules of engagement.	Case study (N = 4) of companies head-quartered in the US
Maruping, Zhang, & Venkatesh (2009) Coordination in software project teams	Software project teams are adopting extreme programming (XP) practices. We do not understand the extent to which XP enables software project teams to coordinate expertise well. The authors examined the role of collective ownership (i.e., the extent to which developers on the team are free to make changes to any unit of software code) and coding standards (i.e., extent to which developers in each team adhere to established software coding standards) as practices that govern coordination in software project teams. Specifically, they investigated the relationship between collective ownership, coding standards, expertise coordination, and software project technical quality. Results indicate that collective ownership and coding standards play a role in improving software project technical quality. They also found that collective ownership and coding standards moderated the relationship between expertise coordination and software project technical quality, with collective ownership attenuating the relationship and coding standards strengthening the relationship.	Survey (N = 509) of software developers, organized in 56 software project teams of one large software development firm in the US
	MISQ	
Kanawattanachai & Yoo (2007) Impact of knowledge coordination on virtual team performance	Because we know little about how virtual team members come to recognize one another's knowledge, trust one another's expertise, and coordinate their knowledge effectively, the authors investigated how three behavioural dimensions related to transactive memory systems (TMS) in virtual teams (expertise location, task-knowledge coordination, and cognition-based trust) and their impacts on team performance change over time. Results indicate that, in the early stage of a project, the frequency and volume of task-oriented communications among team members affect expertise identification and cognition-based trust. Once TMS are established, task-oriented communication becomes less important. Generally, this study shows that TMS can be formed even in purely computer-supported virtual team environments.	Longitudinal laboratory study based on a realistic business simulation game (N = 146) with students organized in 38 virtual teams; duration: 8 weeks
	JIT	
Khan & Jarvenpaa (2010) Temporal coordination of events with Facebook	Facebook is increasingly used to organize ad hoc events (i.e., physical gatherings in social groups). The authors examined how Facebook facilitates the temporal coordination of social events. In essence, they found that social groups exhibited differential interactive behaviours before and after the midpoint of when the event was created on Facebook and when the offline activity was going to take place. Interestingly, interactive behaviour was highest before rather than after the midpoint.	Content analysis (N = 294) of Facebook event pages

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Intra-organizational level		
JMIS		
DeSanctis & Jackson (1994) Coordination of IT management	Coordinating IT management is a challenge. Decentralization may result in flexibility and fast response to changing business needs; it may also make systems integration difficult, present a barrier to standardization, and hamper realization of economies of scale. Thus, there is a need to balance the decentralization of IT management to business units with some centralized planning for technology, data, and human resources. The authors illustrate cost-benefit trade-offs related to three coordination mechanisms (structural design approaches, functional coordination modes, and computer-based communication systems).	Case study (N = 1); longitudinal examination of Texaco's IT department over a five-year period
Lederer & Mendelow (1989) Coordination of information systems plans with business plans	The coordination of information systems plans with business plans is important to ensure that IT investments support organizational goals and business processes. The authors identified four major reasons for the difficulty of coordinating IS plans with business plans: 1) unclear or unstable business mission, objectives, and priorities; 2) lack of communication; 3) absence of IS management from business planning process; and 4) unrealistic expectations and lack of sophistication of user managers. Moreover, they identified four actions for resolving this difficulty: 1) encourage business management participation in IS planning, 2) establish an IS plan, 3) rely on business management's planning process, and 4) participate in business management's planning process.	Interviews (N = 20) with top information systems executives employed by medium- to large-sized organizations in diverse industries
Nidumolu (1996) Coordination in software development projects	Horizontal coordination (i.e., the extent to which coordination is undertaken through mutual adjustments and communications between users and IS staff) has a direct and unmediated positive effect on software product flexibility (i.e., the extent to which the software is able to support distinctly new products or functions in response to changing business needs) but is unrelated to either software performance risk or process control (i.e., the extent to which the development process is under control). Moreover, results indicate that vertical coordination (i.e., the extent to which coordination between users and IS staff is undertaken by authorized entities such as project managers or steering committees) enables project managers to bring projects to closure by reducing performance risks and increasing control over the process, whereas horizontal coordination leads to flexible software applications because it allows exploration of ideas and issues.	Survey (N = 64) of managers who reported on software development projects in the banking and other industries
JIT		
Finnegan & Longaigh (2002) Effects of IT on control and coordination	Pan-national corporations need to improve the control and coordination of their spatially dispersed subsidiaries. IT is a crucial tool in changing traditional control and coordination processes in complex environments. The authors' findings suggest that organizations are using IT to change the nature of the relationship between headquarters and subsidiaries in a manner that makes the pan-national corporation more global in orientation. Specifically, the authors found that IT changed operations and decision making processes in subsidiaries in a way that improved global management and local responsiveness.	Case study (N = 1) of a pan-national corporation located in Ireland with 15 subsidiaries
Mentzas (1993) Coordination of tasks in organizational processes	This study discusses several important areas that arise when studying coordination within organizational settings. The discussion focuses on two types of tasks: decision making tasks and routine office processes. Also, this study describes seven issues crucial in analyzing coordination (specification and implementation of coordination, synchronous and asynchronous working phases, information exchange and information sharing, support of sequential and concurrent processing, support of negotiation and conflict resolution, support of analytical modelling, and description of organizational environment).	Conceptual paper

Table 1. IS Literature with Explicit Focus on Coordination from the Senior Scholars' Basket of Eight Journals

	ISR	
Nidumolu (1995) Effect of coordination and uncertainty on software project performance	The author conducted a study of the effects of coordination mechanisms and risk drivers (e.g., project uncertainty) on the performance of software development projects. The author investigated two coordination mechanisms: vertical (i.e., the extent to which coordination between users and IS staff is undertaken by authorized entities such as project managers or steering committees) and horizontal (i.e., the extent to which coordination is undertaken through mutual adjustments and communications between users and IS staff). Results indicate that project uncertainty increases performance risk and vertical coordination reduces both project uncertainty and performance risk. However, horizontal coordination does not have any significant effect on performance risk. Rather, it has a direct positive effect on project performance. Also, the author found that higher levels of both vertical and horizontal coordination resulted in higher levels of overall performance.	Survey (N = 64) of managers who reported on software development projects in the banking and other industries
	JSIS	
Shih (2006) Email and cooperative work	This study revealed the relationship between two "technology-push" factors (i.e., perceived usefulness and perceived ease of use) and email coordination performance. In essence, email functionality helped experienced users to coordinate task, save time, reduce workload, and improve work outcomes. Also, the author found that perceived information-sharing norms were positively related to email coordination performance, which indicates that establishing an active communication context supports coordination. Specifically, information sharing allowed individuals to cope with ambiguity, which reduces conflicts among individuals. Moreover, results indicate that interdependence among tasks was positively correlated with perceived information-sharing norms, which demonstrates that high interdependency among tasks pushes individuals to develop strong information-sharing norms. The author also reports that high predictability of tasks makes it possible for individuals to achieve cooperative work by following existing procedures.	Survey (N = 295) of office information workers from 15 companies in Taiwan
	MISQ	
Williams & Karahanna (2013) Coordination processes underlying IT governance	Large organizations face challenges in balancing demands for centralization of IT that supports cost and service efficiencies through standardization while providing flexibility at the local unit level (e.g., to meet unique business needs). As a result of this situation, many organizations have adopted hybrid federated IT governance (ITG) structures to find this balance. This specific ITG approach, however, requires various means to be coordinated effectively across the organization. This study helps to explain the coordinating process and the coordination outcomes underlying this specific ITG approach.	Case study (N = 1); longitudinal examination in a large public institution in the United States; focus on two different coordinating efforts: IT Advisory Council and Business Process Analysis Exploratory Group
	ISJ	
Wiredu (2011) Functions of telefonferences for coordinating global software development	A major procedure to cope with the challenges related to geographically distributed software development is coordination via teleconferences. We do not fully understand the specific functions of these teleconferences for coordination purposes. The author analyzed the functions of teleconferences held by globally distributed software engineers to coordinate their work in the face of global distribution of resources, cross-site information interdependencies, and rapidly changing software requirements. In essence, the author identified several functions of teleconferences, all of which help managing interdependencies: it is a platform for mutual understanding, new task allocations, and learning, a precursor for agile development, and a resource for ready access to information and for multitasking.	Interviews (N = 13) with software developers distributed across three sites in the US and one in Ireland

Table 1. IS Literature with Explicit Focus on Coordination from the Senior Scholars' Basket of Eight Journals

Inter-organizational level		
ISR		
Bapna, Barua, Mani, & Mehra (2010) Coordination in multisourcing	When multiple vendors have to collaborate to deliver end-to-end IT services to a client, the choice of formal incentives and relational governance mechanisms depends on the degree of interdependence between the various tasks and the observability and verifiability of output.	Conceptual paper
Bhattacharya, Gupta, & Hasija (2014) Coordination in joint product improvement	The developed framework accounts for the prevalence of gain-share contracts in the IT industry's joint improvement efforts, and it provides guiding principles for understanding the increased role for customer support centers in product improvement.	Mathematical modelling
Im & Rai (2014) IT-enabled coordination for ambidextrous inter-organizational relationships	The authors define contextual ambidexterity of an inter-organizational relationship (IOR) as the ability of its management system to align partners' activities and resources for short-term goals and adapt partners' cognitions and actions for long-term viability. Results indicate that for, both customers and vendors, contextual ambidexterity improves the quality and performance of the relationship and that decision interdependence promotes contextual ambidexterity. Generally, the study demonstrates that IT-enabled operations are key enablers of IOR ambidexterity and that vendors should combine IT capabilities with relationship-specific knowledge that accumulates with relationship duration.	Survey (N = 314) of key informants from both sides of a customer-vendor relationship in the logistics industry in the US
Tan & Harker (1999) Design of workflow coordination	This study models and compares the total expected costs of using decentralized and centralized organizational designs to coordinate the flows of information and work. Based on this comparison, one can define the characteristics of work environments where distributed scheduling methods are more suitable than hierarchical, top-down production approaches.	Mathematical modelling
JMIS		
Clemons & Row (1992) IT and industrial cooperation	The authors apply the theory of transaction cost economics to understand cooperative industrial relationships. They conceptualize cooperation as an effort to increase resource use through higher explicit coordination of value chain activities. However, coordination can create transaction risks (i.e., opportunistic behaviour by the other party). Hence, transaction risks limit the degree of coordination. IT can reduce the costs of coordination while also reducing the transaction risks related to increased coordination.	Conceptual paper
Clemons & Row (1993) Limits to inter-firm coordination through IT	IT can reduce coordination costs and, thus, result in increased cooperation among buyers and suppliers in an industry. However, improved coordination through IT (e.g., checkout scanner systems) and the economic benefits from that coordination are not always realized in practice. The authors found in the consumer packaged goods industry that, despite potential benefits of increased coordination (e.g., reduction in inventory), retailers' resistance to IT innovations exists, and this resistance results from the impact of the coordination mechanisms on bargaining power (retailers perceived that their bargaining power will be decreased under the new coordination structure).	Interview (N = 30) with senior managers (representing both retailers and manufacturers) and secondary data sources (reports)

Table 1. IS Literature with Explicit Focus on Coordination from the Senior Scholars' Basket of Eight Journals

Demirkan, Cheng, & Bandyopadhyay (2010) Coordination strategies in a software-as-a-service supply chain	The IT industry is evolving to cater to the demand for software-as-a-service (SaaS). Two core competencies are necessary in this domain: 1) application service providing (ASP) and 2) application infrastructure providing (AIP). The arrangements between providers in the two domains result in system dynamics that are typical in supply chain networks. The authors examined performance of a SaaS set up under different coordination strategies between ASPs and AIPs. Results show that coordination between the monopoly ASP and the AIP may lead to an outcome with the same overall surplus as a central planner can achieve. Moreover, results indicate that, even though the providers have an incentive to deviate, it is possible to create the right incentives so that the economically efficient outcome is also the Nash equilibrium.	Mathematical modelling and simulation experiments
Gosain, Malhotra, & El Sawy (2004) Flexibility in e-business supply chains	Using IT to create linkages among supply chain partners may have unintended adverse effects on supply chain flexibility. Environmental changes (e.g., increasing business dynamics or changing customer preferences) pose the need for flexibility. The study shows that modular design of interconnected processes and structured data connectivity were correlated with higher supply chain flexibility and that deep coordination related knowledge was critical for supply chain flexibility. Moreover, the authors found that sharing a broad range of information with partners was detrimental to supply chain flexibility and that firms should instead focus on improving the quality of the shared information.	Interview (N = 35) with managers in 16 enterprises in the IT industry supply chain followed by survey (N = 41)
Markus & Bui (2012) Governance of inter-organizational coordination hubs	Business-to-business collaborations are increasingly conducted through inter-organizational coordination hubs (i.e., standardized IT-based platforms provide data and business process interoperability for interactions among the organizations in specific industrial communities). The study examines how and why inter-organizational coordination hubs are governed. Results indicate that coordination hub governance is designed to balance conflicting needs for capital to invest in new technology, for industry members to participate, and for protecting data resources.	Case study (N = 5) of companies: Visa, MERS, GHX, CapWIN, and Nlets
Patnayakuni, Rai, & Seth (2006) Information flow integration for supply chain coordination	Information sharing across supply chains is important to gain economic benefits from integration of business processes across firm boundaries. Results of this study indicate that tangible (i.e., physical assets) and intangible (e.g., trust) resources invested in supply chain relationships make integrating information flows with supply chain partners possible. Also, the study found that relational interaction routines (i.e., the degree to which informal and formal mechanisms are established for the exchange of information and knowledge between a focal firm and its supply chain partners) enable integration of information flows across a firm's supply chain.	Survey (N = 110) with supply chain and logistics managers in manufacturing and retail organizations
	EJIS	
Napier, Mathiassen, & Robey (2011) Firm-level coordination in software companies	Software companies need to improve the efficiency of development processes while at the same time adapting to emerging customer needs; they also need to exploit software products in relation to existing customers while at the same time exploring new technology and market opportunities. Integrating such opposing strategies requires software companies to become ambidextrous. Based on the fact that there is a paucity of actionable advice on how managers can develop such capability, the authors developed a framework that integrates existing theory on contextual ambidexterity with a generic process for improving software companies. Moreover, they offers principles for how software managers can build ambidextrous capability to improve firm-level coordination.	Action research (N = 1) on a small software firm called TelSoft

Table 1. IS Literature with Explicit Focus on Coordination from the Senior Scholars' Basket of Eight Journals

Reekers & Smithson (1996) Electronic data interchange (EDI) in inter-organizational coordination	Electronic data interchange (EDI) is a crucial precondition for inter-organizational coordination. EDI affects the efficiency of coordination, power dependency, and structural aspects of inter-organizational relationships. This study examined the impact of EDI use on the relationships between car manufacturers and their suppliers. The examination is based on three theoretical approaches; namely, transaction cost analysis, resource dependence theory, and the network perspective. Results indicate that EDI helps rationalizing operations both on the manufacturer and supplier side. However, the findings also show that manufacturers can optimize their production at the expense of their suppliers, which may have negative effects on the cooperation with suppliers, which is an obstacle to establish long-term partnerships.	Interview (N = 17) with representatives from German and British car manufacturers and supplier organizations and analysis of documents
	JIT	
Van Liere, Hagdorn, Hoogeweegen, & Vervest (2004) Coordination in a business network	IT reduces the costs for coordination and, with the increasing standardization of business processes and the application of modularity at the process level, leads to embedded coordination. This study describes how three unconnected business networks were integrated using standardization and modularity mechanisms. The study reports that embedded coordination results in improved performance of the business network under the condition that standardization is enforced.	Case study (N = 1) of ABZ, a trusted Business Service Provider in the Dutch insurance industry
	IT artifact level	
	ISR	
Mark & Bordetsky (2000) Groupware system design	The authors illustrate problems that groupware users faced with restricted feedback about others' activities. They found that awareness about such activities can aid users in learning interdependences and in forming conventions to regulate system use and information sharing. Based on their findings, the authors develop a formal system specification.	Case study (N = 1) of a German Government ministry
	EJIS	
D'Aubeterre, Singh, & Iyer (2008) Design of secure business processes with focus on resource coordination	Systems development methodologies often only incorporate security requirements as an afterthought in the non-functional requirements of systems. This gap between systems development and systems security results in software development efforts that often lack an understanding of security risks. Results of the study show that business process models developed using SARC (secure activity resource coordination) artefacts created a higher level of security awareness than a business process model developed using an enriched-use case and activity diagram in users with experience in business process analysis.	Laboratory experiment (N = 84) with students
Note: in case that one study used more than one research method, we indicate this fact in the table. However, we only classify each paper's dominant research method.		

In addition to analyzing relevant papers from the Senior Scholars' basket of eight journals, we studied further papers (predominantly those cited in the reference of the papers listed in Table 1). In essence, this extended analysis of the IS literature shows that research has focused on evaluating the efficacy of different coordination mechanisms, including formal (e.g., authority structures, norms, policies, procedures, steering committees, or task forces) and informal mechanisms (e.g., information and knowledge sharing, trust, or personal relevance, accountability for results, and motivation).

Generally, the main outcome variable in empirical IS studies on coordination is typically related to coordination success. As an example, Ren et al. (2008) present an in-depth case study of a hospital's operating room practices to understand challenges associated with coordinating multiple groups and how IT might support intra-organizational coordination. Results indicate that three factors are of paramount importance for coordination success: 1) trajectory awareness of what is going on beyond an individual's immediate workspace, 2) integration of IT systems, and 3) information pooling and learning at the organizational level. As another example, based on the fact that the extent to which extreme programming (XP) enables software project teams to coordinate is largely unknown, Maruping et al. (2009) investigated the influence of practices that govern coordination in software project teams (e.g., coding standards) on software project technical quality. Their findings show that specific coordination practices may significantly improve the technical quality of software projects. Finally, Reekers and Smithson (1996) examined the role of EDI in inter-organizational coordination in the European automotive industry. Based on theoretical considerations (e.g., transaction cost analysis and resource dependency theory) and case study data from Germany and the UK, they found that EDI enabled both manufacturers and suppliers to rationalize their operations, which indicates that EDI (a technical coordination mechanism) positively affects coordination.

From reviewing the literature, Williams and Karahanna (2013, p. 934) conclude “research has yielded valuable insights into factors associated with success or failure of various mechanisms to achieve coordination in a variety of IT contexts (e.g., project management, outsourced IT project implementation, and inter-organizational networks)”. Also, Williams and Karahanna indicate that combinations of coordination mechanisms, number and composition of participants in teams, level of executive involvement, and several organizational factors (e.g., company size, organizational complexity, and competition) have been related to different levels of coordination, which, in turn, have been correlated with positive and negative organizational outcomes.

However, Williams and Karahanna (2013) conclude that “our understanding of how these various coordination mechanisms produce outcomes in a particular organizational and IT governance setting is underdeveloped” (pp. 934-935). Thus, despite the fact that a rich literature on coordination exists, IS research may benefit from new theoretical explanations that help to better understand coordination success, a main outcome variable in the extant literature. Here, we present such a new theoretical perspective and, thereby, complement existing knowledge that researchers have developed in more than 25 years of coordination research in the IS discipline.

3 The Activity Modalities

In this section, we communicate in a vivid way the gist of the notion of activity modalities. We stress that the nature of the neurobiological substrate underlying the activity modalities has not changed much if at all since the dawn of mankind. Imagine that an individual could travel some 30,000 years back in time and was one of the hunters in Figure 1 who needed food and material for clothing and arrowheads. What coordinative capabilities must the individual possess to participate in this activity?

First, the individual needs to be able to contextualize the situation (contextualization). With a specific goal (e.g., hunting down the mammoth) and underlying motivation (e.g., getting food) in mind, humans have to develop a basic understanding of the situation in the beginning. Hence, contextualization is fundamental to making sense of actions in a specific situation (Harris, 2009, p. 102). The individual must attend to what is relevant to the activity (e.g., hunters, bows, arrows, actions, shouts, gestures) at the expense of other, irrelevant things. For example, the trees in the background are certainly relevant in the mammoth hunting context because they prevent the mammoth from escaping in that direction. However, the beetles and other insects in the trees are irrelevant. Also, the background in Figure 1 shows beaters who are scaring the prey away with noise and fire. These actions would appear completely counterproductive if seen in isolation: only in the context of the activity do the beaters’ actions become intelligible.

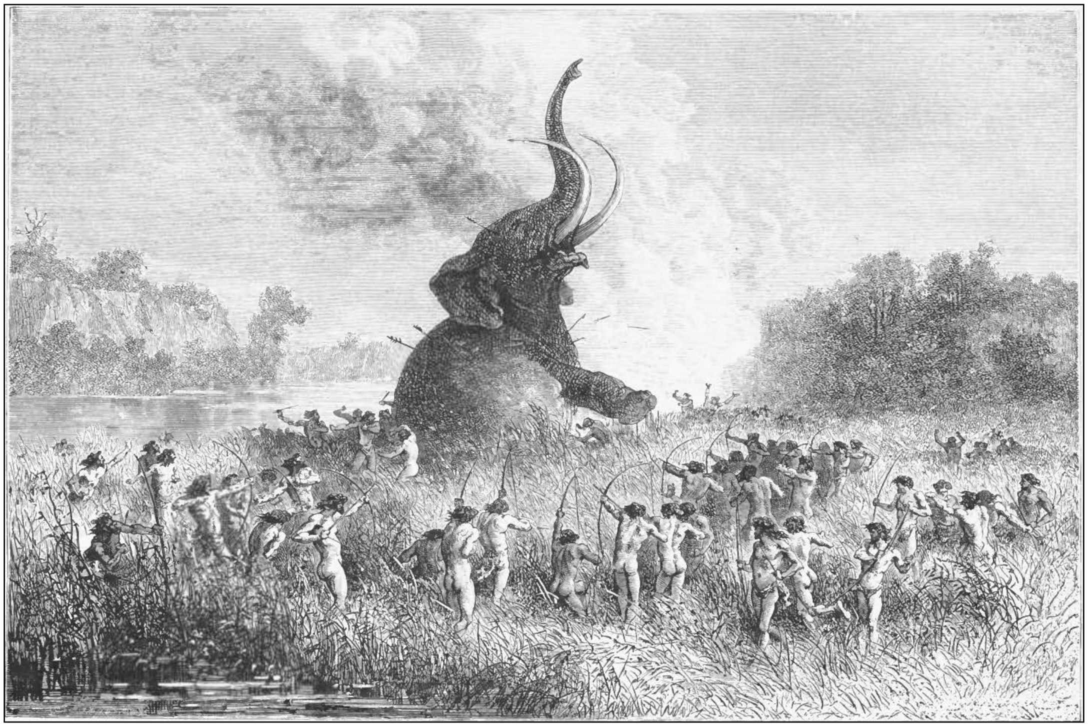


Figure 1. Illustration of Mammoth Hunting, an Ancient Activity Requiring Coordination among Humans (Bryant & Gay, 1883)

Second, the individual needs the ability to direct their attention to the object in focus for the activity (in this case, the mammoth) (objectivation). Also, the individual needs to keep their attention focused on the object until they achieve the goal. The object orientation ability is fundamental for carrying out any kind of action, which Blumer (1969) describes: "Human beings live in a world or environment of objects, and their activities are formed around objects" (p. 68). Moreover, Blumer argues that an object's nature is constituted by the meaning it has for an individual or group; thus, an object materializes for humans in a way that "arises from how the person is initially prepared to act toward it" (pp. 68-69).

Third, human beings must be able to orient themselves spatially in the context (spatialization). The individual needs to recognize how relevant things are positioned in relation to each other and what properties the individual confers on them. For example, the spatial relations between the mammoth, river, trees, and hunters are important (Figure 1).

Fourth, the individual must acquire a sense for the temporal and dynamic structure of the activity as Harris (1996) tellingly expresses in writing that all "human signs ultimately relate to the way our experience of the world is structured by the passage of time" (p. 258) (temporalization). Humans have to predict how actions should be carried out in a certain order for achieving their goal. For example, shooting an arrow involves the steps of grasping the arrow, placing it on the bow, stretching the bow, aiming at the target, and releasing the arrow. As another example, beaters' scaring away the prey by making a noise should only start when the hunters are prepared to shoot the mammoth (e.g., once they have brought themselves into position and stretched the bows).

Fifth, the individual cannot shoot arrows in any way the individual likes (stabilization). Shooting in a wrong direction could result in other hunters being hit rather than the mammoth. Moreover, the individual needs to know where to aim to hurt the mammoth the most. One would accrue an understanding of how to hunt mammoths appropriately after many successful and, presumably, some less successful mammoth hunts. Eventually, this habituation lends a sense of stability to the activity; taking something for granted is essential here because, in this case, rules and norms indicating proper action patterns need not be questioned as long as they work. Stabilization, therefore, is positively affected by an individual's automaticity when performing an activity and by a group's joint experience in similar past activities, which may explain why the proverb "Never change a winning team" is well known worldwide and why it has, in addition to the sports domain, also become relevant in business (e.g., team composition in software engineering projects) and other areas (Jetu & Riedl, 2012; Taxén, 2006).

Sixth, an activity is typically related to other activities (transition). For example, the prey will most likely be cut into pieces and prepared to eat. Individuals will do so in a cooking activity, which, in turn, has its motive (to satisfy hunger) and object (which happens to be the same as for the hunting activity, the mammoth). However, in this context, other aspects of the mammoth become relevant, such as which parts of the mammoth are edible. To participate in or conceive of other activities, humans must be capable of refocusing their attention. In other words: they have to make a transition from one activity to others.

The six dimensions outlined above (contextualization, objectivation, spatialization, temporalization, stabilization, and transition between contexts) are denoted activity modalities. As we discuss in Section 4, the term activity modalities alludes to human sensory and information processing modalities, which indicates that the brain can perceive, process, and integrate multimodal sensory impressions into an action ability described by the activity modalities and their interdependencies. This capability is the same regardless of whether one carries out actions in privacy or together with other individuals as in the mammoth hunt example. However, the ontogenetic development of the coordinative abilities based on neural capacities is essentially determined by the individual's social environment. Thus, activity modalities provide an analytical instrument for investigating the link from neurobiological structures to purposeful social collaboration.

4 The Neurobiological Substrate

We posit that the activity modalities play a central role in coordinating human actions both in individual action and social collaboration. Moreover, we argue that we can find the origin of the modalities in the neurobiological substrate that every healthy human is endowed with at birth. We also assume that manifestations of the modalities occur both in the neural realm as a reorganization of neural tissue (e.g., formation of synapses in the brain through human interaction with the environment) and in the social realm through extracortical devices enhancing coordination (e.g., software tools for coordination). To validate these claims, we need to ground the modalities in both the neural and social realms. Others have reported the significance of the modalities in the social realm (see Taxén, 2006, 2009, 2011, 2012), and, hence, we do not further discuss it in this paper. However, without discussing the relevance of the modalities in the neural realm, they would remain merely heuristic devices without concrete evidence. Thus, in this section, we briefly discuss the activity modalities from a neurobiological perspective.

Researchers have extensively investigated coordination in the neural realm (e.g., Bressler & Kelso, 2001; Bullmore & Sporns, 2012; Doron, Bassett, & Gazzaniga, 2012; Friston, 2011). However, most contributions have focused on the internals of the working brain and characterized the social realm in non-specific terms such as "world" or "environment" (e.g., Knudsen, 2007). As a result, there is a paucity of neuroscience contributions covering both the neural and social realms. Hence, the current state calls for a cautious strategy in grounding the modalities in the neural realm. To this end, we argue that: 1) one can regard coordination as a *complex functional system* based on "the combined work of a dynamic structure of cortical zones working together…[that each] contributes its own factor to the making of a functional system" (Luria, 1964, p. 12); 2) one may model the functional system for coordination as *dependencies between contributing factors*, including the activity modalities; 3) neurological results that indicate contributing cortical zones for each modality exist; and 4) the notion of "functional organ" may provide a link between the neural and social realms (Leontiev, 2009; Luria, 1973). The term "functional organ" signifies that the organization of higher mental functions in the brain result from the specific socio-historical circumstances that an individual encounters during ontogeny.

4.1 Complex Functional Systems

Researchers have long recognized that one must consider mental functions beyond the most elementary ones as complex functional systems (CFS) in which widely distributed cortical zones contribute with a certain factor to the entire CFS (Luria, 1964, 1973; McIntosh, 2000; Bressler & Kelso, 2001). The destruction of any of these zones removes that factor, and leads to the disintegration of the whole functional system (Luria, 1964, p. 12). The same factor may contribute to several CFSs, and a disturbance of that factor may appear as seemingly unrelated symptoms. For example, damage to the occipito-parietal sections of the brain impacts spatial orientation and one's ability to preserve simultaneous spatial schemes. As a result of this primary disturbance, "spatial orientation of movement suffers, spatial schemes of writing are disturbed, [and] defects of counting and of the logical-grammatical schemes (which include this very same spatial factor) occur" (Luria, 1964, p. 14). For our purposes, we consider coordination as a CFS with the activity modalities as contributing factors, which indicates that a disturbance of a cortical area contributing to any modality or their interdependencies will cause the whole coordinative functional system to disintegrate (Sporns, 2013, 2014).

4.2 A Complex Functional System for Coordination

We suggest modeling the CFS for coordination as dependencies between capabilities (where one should apprehend “capabilities” as “factors” in Luria’s (1964) sense). The reason for this change in terminology is that we consider “capability” as a more accessible term in the context of this paper. Figure 2 conceptually represents our model of such a CFS.

Figure 2, which should be read bottom-up, shows relations between entities, including the six activity modalities. A basic capability of the brain is the motivating one, which indicates that the brain can auto-active and continually explore the environment. Next, one needs a sensing capability, which the brain’s different sensory systems (visual, auditory, somatosensory, gustatory, and olfactory ones) realize. Sensing, in turn, is a prerequisite for attention, which also needs alerting (achieving and maintaining a state of high sensitivity to incoming stimuli), orientation (the selection of information from sensory input), and executive attention (monitoring and resolving conflict among thoughts, feelings, and responses) (e.g., Posner & Rothbart, 2007).

The ensuing contextualization capability is dependent on (besides attention) one’s capability to resolve ambiguous percepts, which requires one to retrieve similar percepts from long-term memory. In this context, Bar (2009), for example, writes: “[A]nalogies are derived from elementary information that is extracted rapidly from the input, to link that input with the representations that exist in memory” (p. 1235). With contextualization in place, one can actuate the objectivation, spatialization, and temporalization capabilities. The transition modality is also seen as dependent on contextualization because this modality is involved in focal change from one context to another. Thus, contextualization is a prerequisite for the other modalities. None of these can be actuated if contextualization fails. In particular, discriminating an object in focus requires a contextual background.

Next, the binding capability can be actuated, which signifies the formation of a coherent, pre-motor, actionable percept, which enables one to predict proper action alternatives using similar situations retrieved from long-term memory. What follows is that the motor system executes the chosen action. Its consequences are evaluated and the experience is stored in long-term memory, which contributes one’s forming the stabilization capability.

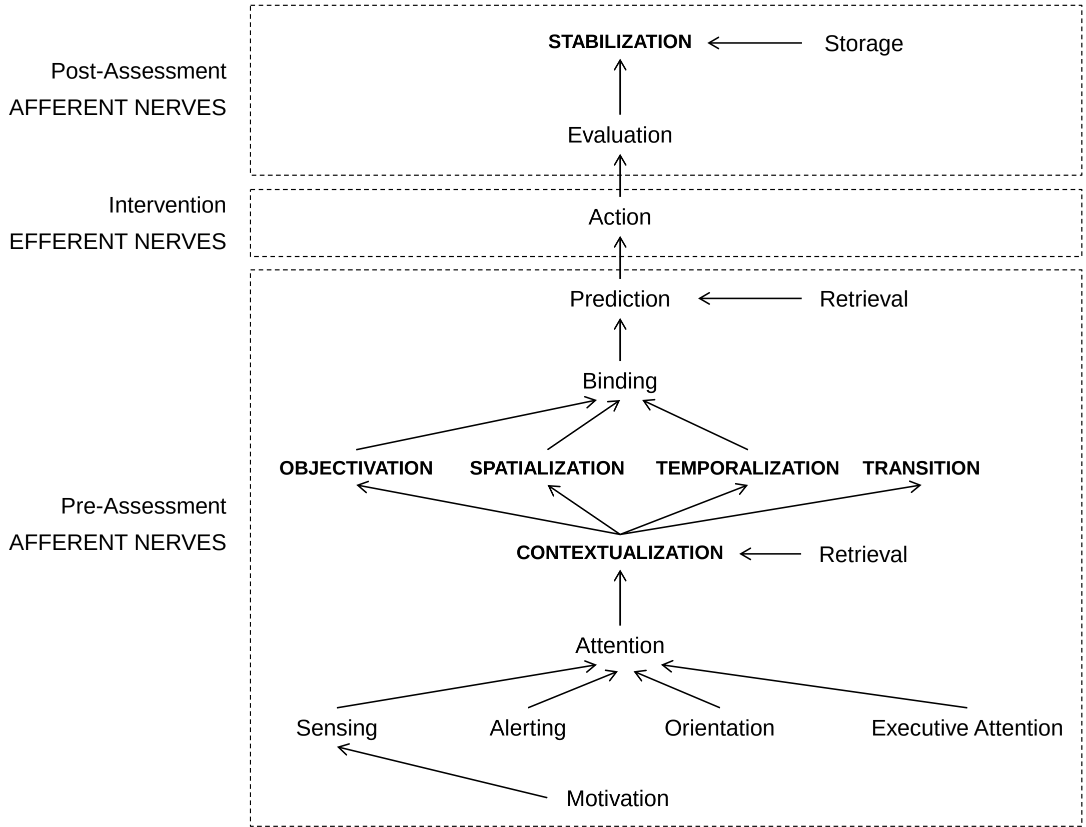


Figure 2. Conceptual Illustration of the Activity Modalities' Neurobiological Substrate

4.3 Neural Correlates of the Activity Modalities

Identifying the neural correlates of the six activity modalities is primarily a challenge for cognitive neuroscience research. Hence, from a behavioral and social scientist's point of view, brain function details, including the experimental paradigms used to reveal those details, are not the main focus. However, what is important is at least a brief report showing that insight on the neural correlates of the six activity modalities is available, which provides evidence that knowledge about the neurobiological substrate does exist but without discussing all the neuronal and molecular details. To this end, we summarize current brain science knowledge on the activity modalities' neurobiological substrate (Table 2). For example, the superior colliculus, a major component of the vertebrate midbrain, is vital for changing focus and to bring attention from one thing to another. As Posner and Petersen (1990, p. 28) note: "Patients with a progressive deterioration in the superior colliculus and/or surrounding areas also show a deficit in the ability to shift attention". If this happens, the transition modality in the neurobiological substrate is inhibited, which, in turn, negatively affects coordination of actions.

Table 1. Neural Correlates of the Six Activity Modalities

Activity modalities	Major neural correlates	Sources (examples)
Contextualization	Anterior cingulate cortex Hippocampus Medial parietal cortex Medial prefrontal cortex Parahippocampal cortex	Bar & Neta (2008), Bar (2007), Bar (2009), Berkman, Falk, & Lieberman (2012)
Objectivation	Amygdala Basal ganglia Fronto-parietal cortex Occipitotemporal regions Thalamus	Coull (1998), Kanwisher & Wojciulik (2000), Kourtzi & Connor (2011), Posner & Rothbart (2007)

Table 1. Neural Correlates of the Six Activity Modalities

Spatialization	Basal ganglia Frontal cortex Hippocampus Parietal cortex	Jeffery, Anderson, Hayman, & Chakraborty (2004), Maguire, Frackowiak, & Frith (1997), Maguire et al. (1998), Maguire et al. (2000)
Temporalization	Basal ganglia Cerebellum Parietal cortex Prefrontal cortex Thalamus	Cook & Pack (2012), Genovesio, Tsujimoto, & Wise (2006), Jin, Fujii, & Graybiel (2009), Teki, Grube, Kumar, & Griffiths (2011)
Stabilization	Amygdala Hippocomapus Mirror neuron system Orbitofrontal cortex Striatum	Clark & Squire (1998), Niv & Montague (2009), O'Doherty (2004), Spunt & Lieberman (2013)
Transition	Amygdala Anterior cingulate cortex Basal ganglia Fronto-parietal cortex Occipitotemporal regions Superior colliculus Thalamus	Kanwisher & Wojciulik (2000), Kourtzi & Connor (2011), Posner & Petersen (1990), Weissman, Gopalakrishnan, Hazlett, & Woldroff (2005)

Note: bear in mind that complex cognitive functions "are organized at a global level in the brain and that they arise from more primitive functions organized in localized brain regions" (Bressler & Kelso, 2001, p. 26). Thus, the neural implementation of a mental process is based on activity in more than one brain area, and each area in the brain contributes to the neural implementation of more than one mental process. Researchers have found the examples of neural correlates given in Table 2 to contribute to a specific modality; thus, it is a necessary cortical area. However, that does not mean that it is also sufficient.

4.4 Linking the Neural and Social Realms through Functional Organs

The relationship between phylogenetically evolved morphological features of the brain and the ontogenetic development of the individual is indeed a tricky problem. This problem has been the focus of scholars such as Lev Vygotsky, Aleksei Leontiev, and Alexander Luria, and a common notion in their thinking is that the socio-historical environment, which an individual encounters during their lifespan, plays a decisive role in their forming higher mental functions.

As such, the brain is not "ready-made" at birth but formed "under the influence of people's concrete activity in the process of their communication with each other" (Luria, 1964, p. 6)[8]. External, historically formed artifacts such as tools, symbols, or objects "are *essential elements in the establishment of functional connections between individual parts of the brain*, and that by their aid, areas of the brain which were previously independent become the *components of a single functional system*" (Luria, 1973, p. 31, emphasis in original). Such elements "*tie new knots in the activity of man's brain*, and it is the presence of these functional knots or, as some people call them, 'new functional organs'…, that is one of the most important features distinguishing the functional organization of the human brain from an animal's brain" (Luria, 1973, p. 31, emphasis in original). A striking example is that brain-imaging studies of musicians have revealed structural changes in the brain as a result of musical training. For example, Zatorre et al. (2007) write that "musicians have greater grey-matter concentration in motor cortices…showing that expert string players had a larger cortical representation of the digits of the left hand" (p. 554). For coordination, this fact implies that the development of individual, coordinative capabilities is intrinsically bound to coordinative devices developed during particular social and historical circumstances. To efficiently contribute to establishing coordinative functional organs in the brain, such devices should be designed in compliance with the activity modalities.

[8] Despite the fact that neuroscience has tremendously advanced since Luria's publications (1964, 1973), his groundbreaking insights into the social impact on higher mental functions is still highly relevant today (Lamdan & Yasnitsky, 2013).

In summary, the gist of the activity modality approach towards coordination is that it provides an analytical link between the neural and social realms. In this capacity, one can see the model of the neurobiological substrate in Figure 2 as a boundary object (Bowker & Star, 1999). Towards the neural realm, the modalities indicate a possible way for connecting extant neuroscience results to the social realm, and, towards the social realm, the modalities indicate how one should design coordinative means to be in connection with the modalities. Information systems are one class of such means which we discuss in Section 5.

5 Information Systems and the Neurobiological Substrate

The activity modality perspective implies a certain way of apprehending information systems. If we posit that one purpose of information systems is to support coordination in organizations, we can regard the IT artifact (e.g., a software tool) an extracortical device involved in forming functional organs of those individuals using the IT artifact. Therefore, one may see an information system as the joint result of the IT artifact and the ensuing functional organ in the brain developed through engaging with the artifact. Consequently, there is no such thing as *the* information system since the functional organ is idiosyncratic for each individual using the IT artifact.

To further explicate the activity modalities' neurobiological substrate in relation to the IS domain, we used a cyclic model of human action that Goldkuhl (2009, p. 385) proposes. This model, referred to as "elementary interaction loop" (EIAL), comprises three stages: pre-assessment, intervention, and post-assessment. These stages can be related to the neurobiological substrate as Figure 2 shows.

In the pre-assessment stage, the individual tries "to work out the possibilities of acting. What are the circumstances in the environments? In what ways is it possible to act? The individual perceives and assesses the action environment and its affordances before intervening into it" (Goldkuhl, 2009, pp. 390-391). Apparently, tools that help one accomplish the goal are essential in this stage. For example, bows and arrows are important tools in the mammoth hunting example. In contemporary environments, the IT artifact is a major tool that helps individuals accomplish goals both in private and organizational contexts. Thus, the capabilities of IT artifacts are informative at this stage.

One interacts with the artifact to satisfy their need for information and, thereby, enable subsequent action. As an example, a software engineer may search for a particular piece of information in a groupware tool without which further the software engineer cannot perform actions in the software-development process. From the activity modality perspective, information has to comprise everything relevant in the domain, including its target, relevant elements in the context around the target, possible action alternatives, established norms, and dependencies to other activity domains (see Ko, DeLine, and Venolia (2007) for a software engineering example).

The pre-assessment stage affects capabilities in the neurobiological substrate from motivation up to prediction (Figure 2). These are actuated to prepare the individual for acting in the world. In this stage, nerve impulses have an afferent character; that is, they go from the periphery of the body to the brain. Against this background, we may say that acting with an IT artifact in the pre-assessment stage is *afferent* in nature; the effects are directed towards the inner realm, not the external.

In the intervention stage, actions, including those based on an IT artifact, intend to make a difference in the external realm. In the mammoth example, a hunter may shoot an arrow toward the animal or communicate with the other hunters via gestures. In contemporary environments, managers make strategic decisions, or software engineers program lines of source code. Importantly, intervention may also aim at influencing other individuals by communicating through an IT artifact by, for example, informing someone or requesting something.

In the neurobiological substrate, the action capability is actuated. Nerve impulses have an efferent character; that is, they carry nerve impulses away from the brain to effectors such as muscles (via the spinal cord) or glands (via neuroactive hormones). However, before such impulses are transmitted, motor circuits have to become active in the brain: these circuits include the premotor cortex, posterior parietal cortex, supplementary motor area, basal ganglia, cerebellum, and the speech production areas located in left inferior frontal lobe (Dehaene, Kerszberg, & Changeux, 1998). In the intervention stage, effects of acting with an IT artifact are efferent in nature to produce some kind of effect in the external realm.

In the post-assessment stage, an individual observes the effects of the intervention. Important questions are: was the action successful with respect to goal accomplishment? If not, what are the reasons? Have expectations been met? The effects of post-assessment are directed inwards; that is, nerve impulses have an afferent character in this stage again. In the neurobiological substrate, the evaluation capability is actuated, and the result is stored in long-term memory for subsequent retrieval to guide further actions and, hence, contribute to the stabilization modality. From an IT artifact perspective, in this stage, users evaluate what is significant on the interface (e.g., error messages, feedback from other individuals, or guidelines for further action). Again, the effects produced by the IT artifact are afferent in nature.

6 Implications for the Information Systems Domain

In this paper, we discuss evidence showing that the six activity modalities have a specific neurobiological basis in the brain, which suggests that the modalities have provided significant value to humankind during evolution. In this section, we discuss important implications of this new conceptualization for IS research and practice based on two concrete application domains: project management and design of collaborative software. We chose these example domains because they are major areas in IS research (Sidorova et al. 2008; Steininger et al. 2009) that are interesting from both a theoretical and practical perspective. Importantly, we stress that our new conceptualization holds value for coordination research on all four levels of analysis that we observed in prior IS coordination research (see the review in Table 1); namely, 1) group, 2) firm (intra-organization), 3) firm (inter-organization), and 4) IT artifact (design science). In this way, our new approach provides a high-level theory to explain coordination success or coordination failure and, hence, is independent from a specific level of analysis.

6.1 Project Management

Several studies have found that coordination is a critical success factor in IS projects, including enterprise system implementation, software development, and outsourcing (see, e.g., Table 2 in a review paper by Jetu and Riedl (2012, p. 462)). Jetu and Riedl define coordination as the “existence of proper organization and monitoring of the project team’s activities (goals and resources) to better meet schedule, quality, budget, and expectations” (p. 481). This definition highlights that project leadership (e.g., a project manager) is responsible for project coordination, including all project stakeholders such as IT staff, users, and consultants.

In contemporary project management, a key challenge is to fully understand and reflect the nature of coordination among project team members that either drives or undermines project success. The conceptualization of coordination based on the six activity modalities provides a lens through which project leadership can better understand both project success and project failure. Such a lens is urgently needed because the IS literature often does not offer more than the mere conclusion that coordination is important for project success, which the following example from the enterprise resource planning (ERP) domain exemplifies (Nah, Zucherweiler, & Lau, 2003, p. 17): “Teamwork and composition in the ERP implementer–vendor–consultant partnership is another key factor. Good coordination and communication between implementation partners are essential.”.

Imagine that an individual is a project manager responsible for implementing an ERP system serving different units in an organization. The individual could use the conceptualization of coordination (Figure 1) in at least three ways. First, the individual could use it ex ante (i.e., before the actual implementation) to plan the execution of the project. The purpose of this ex ante application would be to pose and address major questions in all six activity modality dimensions to avoid coordination problems during project execution. Second, the individual could use it during actual project execution primarily in the case that problems occur. The fact that coordination is so central for project success means that detailed reflection on the constituents of coordination would contribute to a better understanding of the root causes of the problem. The purpose of this application would be to use the conceptualization of coordination as a diagnosis instrument. Third, the individual could use it also ex post (i.e., after project completion) to structure lessons learned. The individual could categorize what was good and what was not along the six activity modalities. For example, an ex post evaluation could reveal that the actual state of an organization (e.g., strategies, tasks, business processes) has been documented well before the project start, a fact that would positively affect contextualization. However, the evaluation could also reveal that the order of implementation of different ERP modules was not optimal, which would negatively affecting temporalization.

Table 3. The Six Activity Modalities, General Questions, and ERP Sample Questions

Table 3. The Six Activity Modalities, General Questions, and ERP Sample Questions

Activity modalities	General questions and ERP sample questions (italics)
Contextualization	• What is the context of a specific situation? • What is relevant, what is not? • How is the specific situation related to other contexts impacting on the current one? *Which organizational units are impacted by the ERP project? Do we understand how? Which capabilities of the ERP system are relevant in each unit? Who are the stakeholders involved in the project? Does the top management explicitly support the implementation? Are there sufficient resources to manage the project efficiently?*
Objectivation	• What is the target object? • Is there a clear and simple model of the target that all stakeholders can easily understand and agree upon? • What kind of strategy exists to achieve a common understanding about the target? • Are the individuals and the group prepared to act toward the object? *Who has selected the ERP system and why? What are the major characteristics of the ERP package? Which modules are to be implemented? Does the IT staff have experience with the ERP package?*
Spatialization	• What kind of information is relevant in this context? • How are information entities related to each other? • How are the entities characterized in the context? • What is the current position? • How did we get from the current position to the target position? *How can the relevant information be managed in the ERP system? What about relations and attributes?*
Temporalization	• What is the logical order of activities to best accomplish a given goal? • Which activities can be executed parallel, and which ones not? *Does the new ERP system support current workflows or has the system been customized and/or the processes redesigned? Is there an implementation strategy describing the course of action, and how has it been developed? Is the time schedule very tight, or does it offer a time buffer? Are the main stakeholders aware of the project's critical path and the milestones?*
Stabilization	• How often is the activity performed by the individuals and the group? • Are there norms which define how an activity could, or should, be performed? *Is a well-rehearsed project team available? Do the project manager and the consulting firm have professional experience? Are best practices and frameworks used in the project?*
Transition	• Is there a common understanding about how different activities should interact? • What is the new target object? • How should attention be redirected to the new target object? *Does consensus exist about how the ERP system should interact with other IT systems in the organization? Is there agreement on what information should be transferred between the systems and how this should be done technically? Which legacy system is currently in use? Can data be transferred from the legacy system to the ERP system? Is there a specific event which constitutes the formal end of the project? Is there a meta-project management coordinating parallel IS projects in the organization? Do formal mechanisms exist to document lessons learned?*

Table 3 summarizes the six activity modalities along with general questions in each dimension. The intended result of posing these questions is to enforce the homomorphism between the project context and the neurobiological substrate of participants as much as possible. The general questions are generic in nature and, thereby, hold application potential in a large number of IS domains. ERP project managers, therefore, should state the questions more precisely, with the consequence that each domain will include a multitude of questions in a specific project context. We state ERP sample questions in Table 3 (in italics). Interested readers can find further critical factors in the ERP literature (see, e.g., Holland & Light 1999; Kim, Lee, & Gosain, 2005; Umble, Haft, & Umble, 2003).

6.2 Design of Collaborative Software

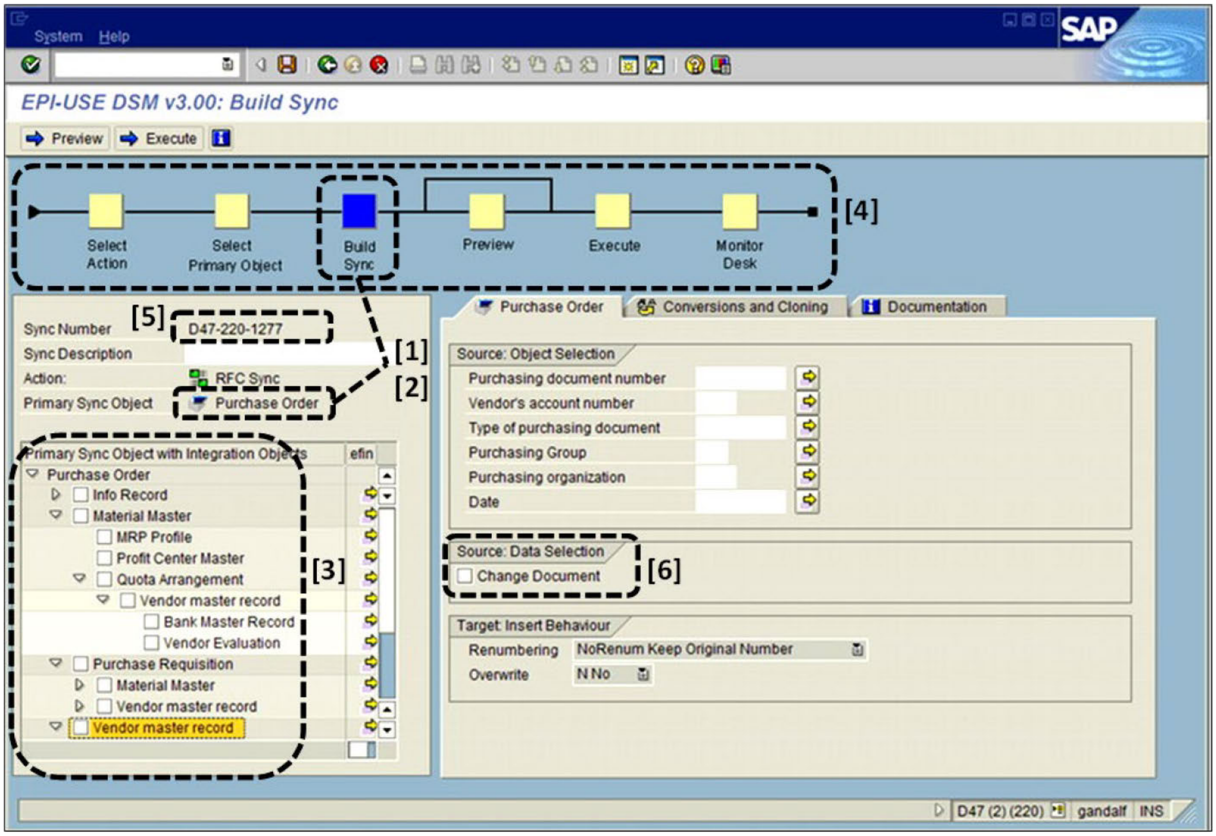
Another important application domain of our conceptualization of coordination is the design of collaborative software. This type of software, also referred to as groupware, is application software designed to help people accomplish a common goal. In the early 1990s, Ellis, Gibbs, and Rein (1991) developed the following definition: “Computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment” (p. 40). The main purpose of collaborative software is to facilitate interaction among group members (e.g., through exchange of information and documents) because such facilitation may positively affect both the interaction process and the outcome of that process (e.g., a software product). Types of collaborative software range from electronic calendars, wikis, and project-management tools to more specialized applications such as groupware for collaborative software engineering (e.g., de Souza, Quirk, Trainer, & Redmiles, 2007).

A major question in this domain concerns the design of the user interface. So far, several papers have focused the design of collaborative software. Based on specific application scenarios, each of these studies have suggested specific software features and interface designs (see, e.g., Ellis et al., 1991; Grudin, 1994; Gumienny, Gericke, Dreseler, Meyer, & Meinel, 2011; Pinelle, Gutwin, & Greenberg, 2003). However, these studies often do not satisfactorily explain why a specific design “A” is better than a specific design “B”. Thus, what is often missing is a solid theoretical grounding of design decisions. In this paper, we argue for a “dual perspective” in IS research that embraces the complementary nature of theoretical research and design science. Specifically, one can use theories (here the conceptualization of coordination based on the activity modalities) to develop IT artifacts that serve a specific purpose and that are referred to as “technological rules” that take the following form: “If you want to achieve Y in situation Z, then something like action [design] X will help” (Van Aken, 2004, p. 227).

We suggest using our conceptualization of coordination as a guiding framework for designing information systems and particularly for designing collaborative software, which would satisfy a basic requirement in IS design science research; namely, that “design decisions should be well justified and based on existing theoretical research” (vom Brocke, Riedl, & Léger, 2013, p. 3). What follows is that a design feature is a candidate for implementation if it contributes 1) to facilitating one of the six activity modalities or 2) to integrating them into a coherent whole. To illustrate this reasoning, we use a SAP graphical user interface (GUI) example (Figure 3).

A basic requirement is that the user can apprehend what the activity is all about. Moreover, the user needs to direct attention to the target object. As the GUI example shows, the activity at hand is “build sync” and the object in focus is “purchase order”. These two features facilitate the contextualization and objectivation modalities (see [1] and [2] in Figure 3). Next, spatialization is facilitated by the features in the left-bottom corner. One can see that the object in focus (“purchase order”) is related to several other items such as “info record”, “material master”, “purchase requisition”, and so forth. These items are all pertinent for the integration of the activity, which facilitates spatial orientation due to the hierarchical nature of the features (see [3]). The temporalization modality is visualized by the activity flow at the top; items that are more to the left precede items that are more to the right (see [4]). Stabilization is usually facilitated by features denoting standards, rules, or norms. As an example, the “sync number” is based on a specific code to develop identification numbers (see [5]). Finally, the transition modality is facilitated by the feature “source: data selection” and “change document” because activating the corresponding checkbox shifts attention to another object (see [6]).

From the example in Figure 3, one can see that features facilitating all six activity modalities are present, which one can expect since the IS needs to facilitate all modalities to be efficacious. However, one could better arrange these features. At the moment, they are positioned in a seemingly ad-hoc way. With the activity modalities as a guiding lens, one could interpret these features in a coherent and systematic way. A GUI design informed by the activity modality framework should proceed along the EIAL model (Goldkuhl, 2009).



Note: Data Sync Manager (DSM) from EPI-USE Labs is a solution for copying of data from production to non-production SAP systems, which multiple individuals typically use in an organization. One can find details for the application at http://www.epiuse.com/products/dsm-product-suite/overview. Number code: [1] contextualization, [2] objectivation, [3] spatialization, [4] temporalization, [5] stabilization, and [6] transition.

Figure 3. Example SAP Screenshot (Source: Original SAP Screenshot from http://softkat.ueu.org/software/mysap.html)

We now outline some example guidelines. First, in the pre-assessment stage, the user seeks to comprehend possible ways to act in the current situation. The activity in which a user is engaged must be clear. This activity needs to be related to other activities on the GUI in such a way that interrelationships with other activities become evident directly. The reason for this requirement is that it is essential to understand the dependencies between activities to integrate a chain of different activities to achieve an overall goal. Second, the object of the current activity should be positioned in the center of the GUI (and, thereby, enhance the objectivation modality). This action could be supported by further means such as highlighting objects (e.g., changing colors or enlarging objects) to help contextualize the activity. Third, the target object's relations to other relevant items might indicate features signifying spatialization. However, because contextualization is an ongoing process, both the inclusion and exclusion of items need to be easy to effectuate. Moreover, because items are not independent from the context in which they appear, it should be possible to characterize them differently depending on the activity in which they are considered relevant. Fourth, features signifying temporalization should be kept together and not scattered around the GUI. The same principle applies for stabilization features. Transition features should be concentrated in the areas in the GUI indicating dependencies between activities. We can expect this measure to foster cognitive information processing. Fifth, a general guiding design principle is to concentrate features pertinent to a modality in specific areas and design these features in concise and effective ways based on which modality is signified. In addition, the interdependencies between the modalities need to be upheld constantly. For example, if a change in an item in one activity is relevant also in another activity, this must be secured by the mechanisms driving the appearance of features in the GUI.

In the intervention stage, the user performs a certain action based on the information processed in the pre-assessment stage. Here, the user needs to be able to identify which features in the GUI it is possible to act on, such as commands and pressable buttons. In the post-assessment stage, the user needs to be informed clearly of the result of these actions to improve habituation (i.e., learning to act proficiently in the current situation). By continuously evaluating the result the EIAL stages, one may modify the GUI to further improve the user's performance.

7 Limitations, Future Research, and Implications

This paper is conceptual. It follows that our theorizing, while informed by evidence from cognitive neuroscience and demanding industrial practices, is necessarily speculative. Thus, we need future research to empirically test the predictions that result from our new conceptualization. For example, future studies could test whether a social collaboration tool (e.g., group decision support system, GDSS) with features conforming to the six activity modalities outperforms a GUI that does not adequately consider the modalities. Relevant dependent variables for corresponding examinations are, among others: time for task completion, satisfaction of the individual group members, decision making consensus, or decision quality. Importantly, the activity modality perspective presented in this paper would serve as the *explanatory mechanism* illuminating why the values of the dependent variables are good or not (e.g., high or low decision quality). Theoretically speaking, we hypothesize coordination success or failure (which is determined by the six activity modalities) to mediate the influence of design features of GDSS on dependent variables such as decision quality.

Once one has empirically established that a GUI with features conforming to the six activity modalities (i.e., the best case) outperforms a GUI that does not adequately or at all consider the modalities (i.e., the worst case), more finely nuanced studies will be necessary to examine the relative importance of each modality. Experimental studies should manipulate one modality while holding constant the other modalities to disentangle each modality's influence on dependent variables. However, such future studies must consider that dependencies do exist among the modalities (for details, see Figure 2). Also, we hypothesize that each modality must reach at least some threshold value to make coordination success possible. Thus, the relationships between each modality and dependent variables are most likely nonlinear.

Another important avenue for future research is to operationalize the six activity modalities in specific IS application contexts. Here, based on the examples of ERP project management and design of collaborative software (see Table 3 and Figure 3), we outline how one could do so. Because our activity modality framework is inherently abstract, operationalization is essential to make the theorizing applicable to IS domains. However, despite the need for operationalization, the high level of abstraction of our framework is a strength because the level of abstraction is positively related to explanatory power.

Another important avenue for future research is to integrate our approach with extant approaches and corresponding constructs. As an example, prior research has investigated the role of trust among interacting partners as antecedent of coordination performance both at the group level (Kanawattanachai & Yoo, 2007) and firm level (Patnayakuni et al., 2006). In essence, results of these studies indicate that trust among interacting partners is crucial for the success of coordinative initiatives. Thus, a crucial question that emerges is whether trust is related to the six activity modalities and, if so, how. One obvious link of trust to our approach is that trust positively affects stabilization, one of the six activity modalities. Research in the IS discipline (Riedl, Mohr, Kenning, Davis, & Heekeren, 2014a; Robert, Dennis, & Hung, 2009) has shown that trust typically develops as a function of past experience with a transaction partner. If another actor has turned out to be trustworthy in prior transactions, trust develops, which positively affecting stabilization, which, in turn, may have a positive impact on coordination success. In contrast, breached trust may destabilize a relationship and may result in higher coordination costs because formal mechanisms (e.g., contracts and their monitoring) are needed to coordinate the relationship.

Intriguingly, the close relationship between trust and stabilization is not only observable on a conceptual or behavioral level. Rather, both factors have overlapping neural correlates. As Table 2 shows, stabilization is related to activity in the amygdala, orbitofrontal cortex, and the striatum, among others. These three brain regions (among others) are also of high importance in trust situations—see an interdisciplinary review by Riedl and Javor (2012) and research on online trust using functional brain imaging technology published in IS mainstream journals such as Dimoka (2010) and Riedl, Hubert, & Kenning (2010a). Generally, the procedure to understand the nature of IS constructs based on their underlying neural correlates in the brain has become increasingly important in the IS discipline during the past several years (see, e.g., Dimoka et al. 2012; Riedl et al. 2010b; Riedl, Davis, & Hevner, 2014b; vom Brocke et al. 2013, and two recent special issues in *JMIS* (volume 30, issue 4) and *JAIS* (volume 15, issue 10)). In this context, Dimoka, Pavlou, and Davis (2011, p. 692) write: “Since there is no one-to-one mapping between mental processes and brain areas, each IS construct could map into several brain areas that jointly underlie the construct. Such mapping can shed light on the nature of the IS construct and whether its neural correlates have specific connotations depending on their exact localization, thus helping to guide their conceptualization”. Based on our example here, we argue that trust and stabilization are closely related constructs (i.e., trust $\rightarrow$ stabilization), a fact that brain research evidence showing that both constructs, at least partly, “reside” in the same brain areas also suggests.

The present paper has important implications. From an academic perspective, the conceptualization provides a theoretical lens through which we can develop a better understanding of success and failures in the IS discipline. Successful coordination is extremely important in many IS research domains (e.g., ranging from project management to interface design); therefore, ignoring a theory that promises to explain variance of coordination success would be a great disservice and presumably significantly impede progress in the IS discipline. From a practitioner perspective, the conceptualization provides a guideline for designing organizational interventions (e.g., planning and evaluation of IT projects) and IT artifacts (e.g., collaborative software).

8 Conclusion

In this paper, we suggest a new conceptualization of coordination in the IS domain based on a neurobiological perspective. Without coordination’s effective operation, both individual and organizational performance would suffer. As such, we argue that coordination is an important but not sufficiently researched domain in the IS discipline and that it holds great potential to explain why some IS initiatives (e.g., ERP projects) and IT artifacts (e.g., GUI) are successful but others not. Drawing on the increasingly available cognitive neuroscience literature, we argue that neurobiological predispositions for coordinating actions do exist. Specifically, we posit that human evolution has resulted in the development of specialized brain circuits that enable coordination, and, hence, evolution theory suggests that modern humans are endowed with a neurobiological substrate enabling coordination of everyday actions. However, despite this predisposition, development of coordinative abilities is affected by human interaction with the environment. Hence, developmental and socio-cultural influences, along with the use of artifacts (e.g., software tools), results in the development of complex functional systems (CFSs). Importantly, the neurobiological substrate we suggest concerns six activity modalities: contextualization, objectivation, spatialization, temporalization, stabilization, and transition. Without the effective functioning of any of these modalities, successful development of CFSs is hampered and coordination is negatively affected. Altogether, this new conceptualization of coordination provides a new perspective on a major topic in the IS domain. It will be rewarding to see which insights future research will reveal.

Acknowledgments

We thank the editor and three anonymous reviewers for their work in providing guidance on ways to improve the paper. Moreover, we thank all other scholars who provided constructive comments on earlier versions of this paper.

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JITTA

JOURNAL OF INFORMATION TECHNOLOGY THEORY AND APPLICATION

JITTA is a Publication of the Association for Information Systems
ISSN: 1532-3416