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BRIDGING KNOWLEDGE BOUNDARIES IN CROSS-FUNCTIONAL GROUPS: THE ROLE OF A TRANSACTIVE MEMORY SYSTEM

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Abstract

One of the key challenges that organizations face when trying to integrate knowledge across different functions is the need to overcome knowledge boundaries between team members. Such boundaries are associated with the different knowledge backgrounds of people from various disciplines and the various contexts and circumstances in which different organizational departments operate. In this research we investigate the role of a Transactive Memory (TM) theory which deals with knowledge coordination in groups - in bridging syntactic, semantic and pragmatic knowledge boundaries in cross-functional groups. The TM theory has been applied recently by Information Systems (IS) researchers to investigate various aspects related to the development and use of IS in different organizational contexts. Our findings, based on a survey conducted in a large Dutch governmental organization, extend the TM theory by showing that a Transactive Memory System negatively influences syntactic, semantic and pragmatic boundaries. Furthermore, our results show that a pragmatic boundary has a positive influence on the existence of the syntactic and semantic boundaries. The paper discusses implications of our findings for the design, maintenance and use of IT-based systems in organizations.

Keywords: Syntactic, semantic and pragmatic knowledge boundaries, transactive memory system, cross-functional group

Introduction

Scholars studying various aspects of knowledge and knowledge management in organizations agree that, while knowledge is a source of competitive advantage and a key driver of innovation, management of knowledge remains one of the major challenges organizations are facing nowadays (e.g. Grant 1996; Lubit 2001; Nonaka 2007). To remain competitive, organizations innovate and create value through cross-fertilization and interactions between experts from various disciplines (McEvily et al. 2004) who bring their know-how based on years of experience to innovation processes. In doing so, integration of knowledge from various disciplines and contexts aims at addressing future needs (e.g. innovation and business transformation). This integration of knowledge facilitates the organization's ability to sense, interpret and respond to new opportunities and threats in a dynamic business environment (Alavi and Tiwana 2002; Vlaar et al. 2008).

One of the key challenges that organizations face when trying to integrate knowledge across different functions (e.g. engineering and marketing) is the need to overcome knowledge boundaries between team members. Such boundaries can be associated with the different knowledge backgrounds of people from various disciplines, and the various contexts and circumstances in which different organizational departments operate (Carlile 2004; Carlile 2002; Gittelman and Kogut 2003), as well as diverse organizational and national contexts (Levina and Vaast 2008), if collaborative situations involve multi-national or globally distributed organizations (e.g. joint ventures or outsourcing). Because of the internal and external dynamics that affect people involved in collaborative work, the circumstances under which collaboration takes place and the goals that a collaborative effort aims to achieve, each situation presents a different combination of boundaries (Levina and Vaast 2008).

Past research has offered various organizational, human-related and ICT-based mechanisms for improving knowledge management within and between organizations. Among these are the following: organizational structures and networks that support knowledge transfer (Hansen 2002; Kotlarsky et al. 2008; Uzzi and Lancaster 2003), inter-personal ties (Ahuja and Galvin 2003; Kanawattanachai and Yoo 2002), trust (Jarvenpaa and Leidner 1999; Ridings et al. 2002), transactive memory systems (e.g. Nevo and Wand 2005; Oshri et al. 2008), formal interventions that facilitate knowledge integration in groups (Okhuysen and Eisenhardt 2002), knowledge representations (Boland et al. 2001), and the use of document management systems and collaborative technologies such as e-mail, chat, teleconferencing, video-conferencing, intranet, electronic forums and meeting systems (Herbsleb and Mockus, 2003; Smith and Blanck, 2002). While these mechanisms have been suggested for improving knowledge management and facilitating knowledge transfer, past research has not examined the impact of different types of knowledge management mechanisms on bridging knowledge boundaries. In this research we attempt to address this gap by investigating the role of transactive memory in bridging syntactic, semantic and pragmatic knowledge boundaries (Carlile 2004; Carlile 2002).

The paper is organized as follows. The next section discusses knowledge boundaries and the mechanisms suggested to help in bridging these boundaries. Then we introduce the concept of a Transactive Memory System (TMS) and discuss its role in bridging knowledge boundaries. We develop a set of hypotheses that suggest the role a TMS plays in bridging knowledge boundaries in cross-functional teams. Then, we present the methodology and results of a survey study within a Dutch governmental organization. The paper concludes with a revised theoretical framework and practical and theoretical implications.

Understanding knowledge boundaries

The competitiveness of firms relies to a great extent on their ability to find relevant knowledge within the organization (e.g. about a product or sub-system design or the expertise of individuals) and to integrate the knowledge of individuals along with the knowledge embedded in physical artifacts and documents into new products, services or other innovations.

Knowledge is typically integrated within groups via a process which takes it from individually "owned" knowledge to the collective level (Okhuysen and Eisenhardt 2002). The success of knowledge integration in groups depends on the boundaries which group members need to bridge (Teigland and Wasko 2003). Some groups are relatively permanent (e.g. functional departments) while others are temporary (e.g. emergency response or project teams). For example, in fast-response organizations such as emergency rooms or disaster recovery teams individuals need to be able to integrate their knowledge and act very quickly to save lives (e.g. Faraj and Xiao 2006; Majchrzak et al.

2007). Project teams are usually formed for longer periods of time: weeks or months. Such teams involve individuals from various organizational functions with different backgrounds and specializations, such as marketing experts, designers, business analysts, programmers and others. The different backgrounds of the group members, as well as the different contexts and politics of the organizational functions or departments they belong to, can create differences in their understanding of the common goals that the group needs to achieve. Moreover, individuals involved in project teams and other temporary groups (e.g. various committees) often need to fulfill not only the goals set for the group they belong to but also to align these goals with the goals and resources of the department or function they represent.

Knowledge boundaries may have various origins, such as limitations in information processing (Galbraith 1973; Lawrence and Lorsch 1967), cultural and political aspects, or the degree to which knowledge is embedded in specific practices and their contexts (Carlile 2002; Kellogg et al. 2006). Actors involved in collaborative activity may experience knowledge boundaries if they use different terminologies, codes, protocols, routines or other (different) means to express themselves and communicate what they accomplish as part of the work and how they do so. Such differences create a syntactic knowledge boundary (Carlile 2002), which can be reduced if a common lexicon is developed and information artifacts, such as standards, repositories and specifications, are made available for the parties involved (Kellogg et al. 2006). Symbolic capital - "the power to name things and institute an order among things" (Levina and Vaast 2008:324) – can improve information processing and facilitate the transfer of knowledge across this boundary (Carlile 2004).

Beyond the existence of a common syntax lies the problem of different interpretations. Knowledge that is embedded in a specific practice or context requires deeper understanding than just a common lexicon and templates (Kellogg et al. 2006). Based on such experiential and situated knowledge, individuals involved in a process that requires knowledge integration make assumptions, often unconsciously, which are not obvious and can even contradict others' assumptions. Carlile (2002) refers to such differences in context, assumptions and meanings as a semantic knowledge boundary. Bridging this boundary requires individuals to understand novel conditions and learn about the sources of these different assumptions. "Translating" knowledge across the boundary can be facilitated through the use of collective stories, cross-functional interactions, boundary spanners/translators and common artifacts (Carlile 2004; Kellogg et al. 2006; Levina and Vaast 2005).

While integrating knowledge in groups usually aims at innovating (e.g. a new product, service or strategy), novelty may generate different interests between participants if it questions key principles, rules or assumptions followed previously in some parts of the organization. Changing ways of doing things requires adjustments in the accumulated knowledge, which may frighten individuals if their expertise and therefore their value in an organization is in danger of being diminished or lost. Carlile (2002) refers to differences that require adjustment in accumulated knowledge as a pragmatic or political boundary. This boundary reflects the political aspects of knowledge as it indicates the existence of differences in interests, existing practices, goals and other aspects that have become common sense in some (local) parts of the organization. Bridging this boundary requires the transformation of existing localized knowledge into new knowledge (Carlile, 2004). This can be achieved through trial-and-error problem solving and the use of boundary objects (e.g. prototypes, common models, diagrams, maps and devices) that can be jointly transformed through collective action (Gasson 2006; Kellogg et al. 2006; Levina and Vaast 2005). For knowledge transformation to take place, common interests need to be developed which would provide a ground for sharing and adjusting the knowledge at a boundary (Bechky 2003; Carlile 2004).

Various studies of knowledge boundaries and ways of bridging them in traditional hierarchical organizations such as cross-functional co-located teams (e.g. Carlile 2004; Carlile 2002; Scarbrough et al. 2004), as well as in more novel post-bureaucratic organizational forms (such as heterarchies where accountability and decision making is distributed between different entities) that operate under conditions of high speed, uncertainty and rapid change (e.g. Kellogg et al. 2006; Levina and Vaast 2008), discuss in depth the notion and sources of knowledge boundaries and the challenges they pose for organizations, and also suggest various mechanisms that could help in bridging these boundaries and in facilitating innovation and collaborative work. For example, Scarbrough et al. (2004) studied learning between projects in project-based organizations where project autonomy presented a challenge to knowledge integration for the wider organization. They identified the emergence of "learning boundaries" that present a challenge to attempts to exploit project-based learning beyond individual projects. Kellogg et al. (2006) developed the notion of a "trading zone" that embraces various cross-boundary coordination practices grouped into display, representation and assembly practices that, when applied in the "trading zone", create visibility and improve understanding of the work done by different actors. Levina and Vaast (2008) found that teams involved in offshore software development experience so-called "status differences" caused by differences in competences, economic resources and interpersonal connections which created knowledge boundaries between members of globally-distributed project teams. Geographical and temporal distance introduced additional challenges by making it more difficult to establish a common lexicon and interpretations, and to develop joint practices between globally distributed team members, necessary for bridging knowledge boundaries (Levina and Vaast 2008). The authors found that the accumulation of particular types of capital (economic, intellectual, social, and symbolic) and the interplay between them helps to reduce these boundaries.

With this enhanced understanding of knowledge boundaries and the challenges impeding the bridging of these boundaries in different types of organizations, the understanding of how knowledge boundaries can be reduced is still limited. Practices for bridging knowledge boundaries offered in the existing literature rely largely on the boundary-spanning practices suggested in the wider literature on boundaries in organizations, including organizational, functional, geographical, identity, temporal, national, professional and hierarchical boundaries (e.g. Espinosa et al. 2006; Gasson 2006; Levina 2005; Levina and Vaast 2005; Lindgren et al. 2008; Pawlowski and Robey 2005; Santos and Eisenhardt 2005; Teigland and Wasko 2003). Boundary-spanning practices discussed in this literature include boundary objects which comprise artifacts such as physical product prototypes, designs in various forms (e.g. drawings, blueprints, sketches), shared Information Technology (IT) tools, standard forms and templates, and individuals who act as boundary spanners (e.g. "translators" and knowledge brokers). The use of these practices has been discussed in specific relation to bridging knowledge boundaries (e.g. Carlile 2002, 2004; Bechky 2003) and adopted for dealing with them, for example through the use of the "trading zones" (e.g. Kellogg et al. 2006).

In this paper, we discuss how knowledge boundaries may be bridged through the lens of a Transactive Memory theory that, from the field of psychology where it was originally developed (Wegner et al. 1991; Wegner et al. 1985), has been widely adopted in IS research and organization science , where it has been discussed in relation to collaborative work (e.g. Jarvenpaa and Majchrzak 2008; Lewis 2004; Majchrzak et al. 2007; Ren et al. 2006), to learning (e.g. Akgun et al. 2006; Lewis et al. 2005; Yoo and Kanawattanachai 2001), to knowledge transfer in global IS teams (e.g. Oshri et al. 2008), IS-based organizational memory (e.g. Nevo and Wand 2005) and to group performance (Liang et al. 1995; Littlepage et al. 2008; Zhang et al. 2007). This perspective is complementary to the existing views on knowledge boundaries that so far have been embedded in the literature on boundaries and boundary-spanning. In the following section we introduce the concept of the Transactive Memory System, followed by a discussion of its role in bridging knowledge boundaries.

The Transactive Memory System

A Transactive Memory System (TMS) has been defined as the combination of individual memory systems and communications (also referred to as "transactions") between individuals. The group-level TMS is constituted by individuals using each other as a memory source. Transactions between individuals link their memory systems: through a series of processes (i.e. encoding, storing and retrieving) knowledge is exchanged which, in turn, reduces knowledge gaps between individuals exchanging knowledge. The majority of past studies on TMS have studied the influence of TMS on performance (e.g. Akgun et al. 2006; Lewis 2004; Lewis et al. 2005; Liang et al. 1995; Reagans et al. 2005; Ren et al. 2006; Yoo and Kanawattanachai 2001) or have focused on antecedents and factors that facilitate development of TMS (e.g. Akgun et al. 2005; Brandon and Hollingshead 2004; Chang 2005; Moreland and Myaskovsky 2000). These factors include familiarity (i.e. past experience of working together), frequency of face-to-face interactions and other formal and informal communications between team members, team stability and trust. Furthermore, TMS has been identified as the facilitator of transferring and sharing of knowledge between team members (Majchrzak and Malhotra 2004; Nevo and Wand 2005; Oshri et al. 2008) and of managing globally distributed expertise (Oshri et al. 2007). It has been argued that the use of IT helps to extend the TMS from small groups that rely largely on inter-personal communications to larger groups and organizations. For example, Nevo and Wand (2005) present a formal architecture for directories of meta-memories required in extended TMS and propose the use of metaknowledge to substitute for the lack of the tacit group knowledge that exists in small groups. Furthermore, the findings of Oshri et al. (2007, 2008) based on research in globally distributed IS development teams involved in offshore IT outsourcing show that the mechanisms through which TMS is activated rely to a great extent on various Information and Communication Technologies (ICT), expertise directories and Knowledge-Management Systems (KMS).

In practice, the development and activation of core TMS processes (encoding, storing and retrieving[1]) is supported by codified and personalized directories (Oshri et al. 2008), as illustrated in Appendix 1. These directories are associated with codified (e.g. Hansen et al. 1999) and personalized memory systems distinguished in the literature (e.g. Blackler 1995), which are related to codification-based and personalization-based knowledge approaches respectively (Desouza and Evaristo 2004; Hansen et al. 1999). With the codification approach, individual knowledge is “made centrally available to members of the organization via databases and data warehouses.” The personalization knowledge approach, on the other hand, “recognizes the tacit dimension of knowledge and assumes that knowledge is shared mainly through direct person-to-person contacts” (Desouza and Evaristo 2004:87). Similarly, the directories that point to where knowledge and expertise reside can either be *codified* (e.g. information systems and technologies, ICT, KMS) or *personalized* (e.g. personal memory or other people’s memories). In other words, transactions between individuals take place through the use of various codified (e.g. various databases and systems) and personalized (e.g. their own or other people’s memory) directories. Such a TMS can be further developed and renewed through a constant update of these codified and personalized directories (Oshri et al. 2008).

The role of TMS in bridging knowledge boundaries

The encoding process in a TMS facilitates the development of a shared “cataloging” system with commonly-known labels (e.g. keywords used for searching a firm’s document portals and expertise directory). This can introduce and encourage the use of a common lexicon between the actors involved in collaborative work and therefore contribute to bridging the syntactic knowledge boundary. Codified directories implemented in the forms of keywords, and/or rules for storing documents and templates, are in line with Carlile’s (2004) suggestion of using taxonomies and also storage and retrieval technologies for bridging the syntactic boundary. This leads to the following hypothesis:

H1: The existence of a Transactive Memory System in a cross-functional group will negatively influence the syntactic knowledge boundary in the group.

Encoding that takes place through personalized directories is based on past experience of working together, through which actors develop shared understanding of the context and learn about the areas of expertise of their counterparts. Therefore, besides facilitating the use of a common lexicon, encoding in personalized directories also helps create shared interpretations, thus contributing to bridging syntactic as well as semantic knowledge boundaries.

Once labels are attached to knowledge (e.g. documents, role descriptions, expertise areas of individuals), a TMS contains a collection of pointers to the location of actual knowledge (e.g. documents, or people who have specific expertise). Personalized pointers to the location of knowledge (i.e. information about who knows what) are stored in the memories of individuals. Codified pointers, such as structures of project folders and portals that are supported by various IT tools, define a structured and consistent approach to storing and updating documents. Once individuals become familiar with these structures, they know where to find relevant documents. If such structures are replicated across various cross-departmental settings (e.g. several projects that involve cross-functional teams), individuals changing from one setting to another and engaging in new projects or initiatives would apply similar logic and rules while searching for relevant information in the new settings. This way, replicated structures and shared mental models (Brandon and Hollingshead 2004; Mohammed and Dumville 2001) would facilitate shared understanding by providing better access to relevant information that could shed light on the sources of differences in interpretations. For example, if the members of a cross-functional group know how and where to find additional information, beyond the documents related to the specific project they are working on as a group, they might be able to find sources of differences in interpretations when facing semantic challenges, through the use of codified IT-based TMS directories. Personalized directories can be even more helpful in bridging the semantic knowledge boundary. Inter-personal relations and social networks play a significant role in situations of uncertainty or potential conflict (e.g. Panteli and Sockalingam 2005). Therefore, knowing “who knows what” and using interpersonal channels to find a

[1] The TMS processes of *encoding*, *storing* and *retrieval* also have been explained through directory updating, information allocation, and retrieval coordination (successively). *Directory updating* is associated with learning who knows what. *Information allocation* is about allocating information to the relevant experts for processing and storage. *Retrieval coordination* referrers to retrieving uniquely stored information for task performance purposes (Wegner 1995; Peltokorpi 2008).

person (outside the group) or information that can explain the sources of differences would be powerful in dealing with the semantic knowledge boundary. Thus we hypothesize the following:

H2: The existence of a Transactive Memory System in a cross-functional group will negatively influence the semantic knowledge boundary in the group.

Jarvenpaa and Majchrzak (2008) have studied a TMS in ego-centered networks where the actors involved in collaborative activities have mixed motives, which is one of the key reasons for the existence of a pragmatic knowledge boundary. According to their study, a TMS improves the ability of individuals with mixed motives to combine their knowledge to solve problems. Along with the TMS, the existence of benevolence-based distrust, which Jarvenpaa and Majchrzak (2008:262) define as "confident negative expectation regarding others' interests that may harm or damage one's own interests", would reduce the perceived risk of exchanging knowledge with others and facilitate bridging the pragmatic knowledge boundary between actors with different goals and interests. Among actors with mixed motives, a TMS would take the shape of knowing "who acts what " rather than "who knows what", based on observing the actions of other actors applying their knowledge (Jarvenpaa and Majchrzak 2008). Thus, being able to predict the actions of others would contribute to bridging the pragmatic knowledge boundary.

Dialogic practices that describe rules of communication and other "semi-structures" that embody rules to help group members to organize their knowledge integration processes in a flexible manner would both help to reveal the differences in interpretation which are the source of the syntactic knowledge boundary and which, if not exposed and understood, may generate tensions creating a pragmatic knowledge boundary (Faraj and Xiao 2006; Jarvenpaa and Majchrzak 2008).

In the existing literature, the concept of TMS is closely related to the concepts of collective mind (the ability of individuals to heedfully interrelate their actions (Weick and Roberts 1993; Yoo and Kanawattanachai 2001)) and shared mental models (the extent to which individuals share the same understanding about tasks, expertise and people, and link these understandings in their own minds in similar fashion (Brandon and Hollingshead 2004)), which are both important for bridging pragmatic as well as semantic knowledge boundaries. Through the development of shared mental models and a collective mind actors learn about sources of different interpretations, create joint understanding of issues and artifacts, and modify their knowledge. A TMS which is constantly updated through transactions between individuals facilitates the development of a collective mind (Yoo and Kanawattanachai 2001) and of shared mental models (Brandon and Hollingshead 2004; Mohammed and Dumville 2001; Peltokorpi 2008), thus contributing to bridging knowledge boundaries. This leads to the following hypothesis:

H3: The existence of a Transactive Memory System in a cross-functional group will negatively influence the pragmatic knowledge boundary in the group.

Codified IT-based TMS directories available for members of cross-functional groups embrace corporate-wide document management systems, KMS, portals and expertise directories (e.g. "yellow pages") that can be accessed by members of different departments. Personalized directories develop through the joint experience of working together in the past, having a common background, and through informal social networks. Therefore it is likely that the majority of personalized pointers of individuals would point to knowledge that resides within their department and less so to knowledge outside their department. Thus we hypothesize:

H4.1: In cross-functional groups the use of codified directories will positively influence the existence of TMS

H4.2: In cross-functional groups the use of personalized directories will positively influence the existence of TMS

H4.3: In cross-functional groups the influence of codified directories on the existence of TMS will be stronger than the influence of personalized directories

Figure 1 depicts our theoretical model, which illustrates the relationship between knowledge boundaries, TMS and TMS directories in cross-functional groups.

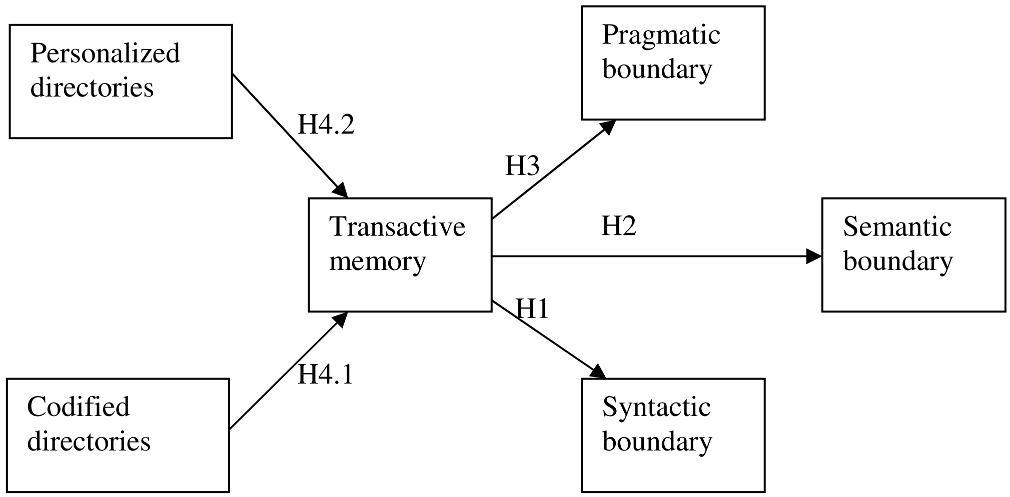

Figure 1. Theoretical model

Hypotheses H1-H3 suggest the relationship between a TMS and syntactic, semantic and pragmatic knowledge boundaries. Hypotheses H4.1 and H4.2 suggest that in cross-functional settings codified and personalized directories will have a positive influence on the existence of TMS, and that the influence of codified directories will be stronger than of personalized directories (H4.3).

Research design and methodology

In order to test the theoretical model, a survey study was conducted within a large Dutch governmental organization. The focus of the survey was on collaboration and knowledge sharing between the different sectors in this organization, which were involved in tasks concerning education, culture and welfare in a large Dutch city – from strategy and policy-making to building playgrounds and school inspection. The different sectors had strongly differing areas of expertise, which posed the danger of creating isolated silos in the organization. As the tasks of the organization increasingly demanded an integrated approach towards issues, management saw this as a potential problem and thus wanted to obtain insights into how inter-sectoral knowledge-sharing could be stimulated. To this end, employees involved in knowledge-intensive work that requires collaboration between these sectors were asked to complete a questionnaire. A request was sent out to 360 selected organizational members to complete the online survey. Ultimately, 150 respondents (41%) completed the survey. A majority of respondents (60%) were based in one location (Den Haag), 20% at another location (Thorbeckelaan), and the rest distributed between various locations.

Measures

In the survey, all variables - unless otherwise reported - were measured using 1-5 point (strongly disagree – strongly agree) Likert-type scales. The scale for Transactive Memory System combined items from a scale used by Jarvenpaa and Majchrzak (2008), who modified the TMS scale developed by Lewis (2003), and items developed by Van den Hooff and Huysman (2009), adapted for the purpose of this research. The TMS scale consisted of three items, such as "I know which colleagues from other sectors have relevant knowledge". A higher score on this scale means that (in the perception of the respondent) that a TMS exists to a higher degree.

The scales for the knowledge boundaries were newly designed, but were conceptually validated by comparing them to Carlile's (2004) definitions and by asking experts (established academics working on issues related to TMS and knowledge management, including Carlile) for their feedback. The scales for each boundary consisted of two items. An example of an item for the syntactic boundary scale is "Colleagues from different sectors have their own jargon when they communicate about work". An example of an item used to measure the semantic boundary is "Working together with colleagues from other sectors, we often have different interpretations about the meaning of things". The pragmatic boundary was measured by statements such as "Working together with colleagues from other sectors, it is often difficult to arrive at a shared point of view on a possible solution". The scales for codified and personalized directories consisted of items measuring the extent to which different instruments were used by respondents to share knowledge: instruments like work meetings with colleagues from other sectors for personalized directories, and instruments like the intranet, documents and websites for codified directories. The wording of the items for each scale is shown in Table 1.

Confirmatory factor analysis (CFA) was used to assess the psychometric properties of the composite measures (all variables except use of online and use of face-to-face). AMOS[2] 5.0 with maximum likelihood estimation (MLE) was used to assess the measurement model. After deletion of a number of items, the measurement model in which the composite scales (latent variables) were related to the items outlined in Table 1 produced a satisfactory fit: the ratio of Chi square to degrees of freedom scored 1.70, which indicates a good fit of the model to the data (critical value is 2.0). Furthermore, the Goodness of Fit Index (GFI) reached a satisfactory level at 0.89, the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) scored sufficiently close to 1 at 0.93 and 0.90, and the Root Mean Square Error of Approximation (RMSEA) scored 0.07, indicating a reasonable error of approximation. As such, the results confirmed the dimensionality of the solution, and suggested convergent and discriminant validity. We further studied the validity and assessed the reliability of the measures by computation of Composite Reliabilities (CR) and Average Variance Extracted (AVE) scores, shown in Table 1.

Table 1: Results of Confirmatory Factor Analysis

Scale (items)	Stand. factor loading	CR	AVE
Transactive memory[(1)]		**0.822**	**0.611**
I know which colleagues from other sectors have relevant knowledge.	0.623		
Colleagues from other sectors know which knowledge I have.	0.876		
I know what knowledge is relevant to colleagues from other sectors.	0.823		
Pragmatic boundary[(1)]		**0.637**	**0.550**
If someone comes up with a solution that requires colleagues from other sectors to change their point of view, they have difficulties with that.	0.592		
Working together with colleagues from other sectors, it is often difficult to arrive at a shared point of view on a possible solution.	0.770		
Semantic boundary[(1)]		**0.771**	**0.570**
Working together with colleagues from other sectors, we often have different opinions on goals and possible solutions.	0.812		

[2] AMOS is a software package that supports structural modeling, analysis of covariance structures, or causal modeling. This package basically enables the testing of a set of regression equations simultaneously, providing both parametric statistics for each equation and indices that indicate the ''fit'' of the model to the original data.

Working together with colleagues from other sectors, we often have different interpretations about the meaning of things.	0.772		
Syntactic boundary(1)		**0.697**	**0.512**
I am not aware of what happens in other sectors.	0.574		
Colleagues from different sectors have their own jargon when they communicate about work.	0.833		
Personalized directories(2)		**0.700**	**0.538**
Work meetings with colleagues from other sector	0.741		
Working with new colleagues from other sectors	0.726		
Codified directories(2)		**0.845**	**0.530**
Corporate Intranet	0.731		
Division Intranet	0.626		
Documents on the network	0.526		
E-mail	0.917		
Third party websites	0.779		

(1) These items use a 5-point disagree–agree response format, in which 1- *strongly disagree,* 2-*disagree,* 3-*neutral,* 4 -*agree,* and 5-*strongly agree.*

(2) These items use a 5-point response formal indicating frequency of use, in which 1- *do not use at all*, 2-*use rarely*, 3 – *use sometimes*, 4- *use regularly*, and 5- *use often*.

Table 1 shows the composite scales, the items measuring these scales, the factor loadings of these items derived from the CFA, as well as the CR and AVE values. These results show support for both the reliability and the validity of the measures: all factor loadings exceed 0.5 (the minimum value according to Hair et al. 2006), while the majority of these loadings is higher than 0.7. Furthermore, most CR values are equal to or above 0.7 (indicating sufficient reliability) and the AVE values all exceed 0.5, indicating a sufficient degree of convergent and discriminant validity of these scales. The scale for the pragmatic boundary shows an insufficient composite reliability value (0.64), but since the factor loadings are sufficient and the AVE value is satisfactory, it was decided to retain the scale. The convergent validity of the measures was confirmed by the factor loadings (CFA), composite reliabilities and AVE values. Discriminant validity was further confirmed by comparing the within-construct item factor loadings to across-construct item loadings. Since all within-construct item loadings were high enough (exceeding 0.5), and clearly higher than the cross-loadings, discriminant validity could be assumed. Finally, scores were compared with the squared correlations among the constructs. All AVEs exceeded the values of the squared correlations among the constructs in the corresponding rows and columns (see Table 2). As such, discriminant validity was confirmed.

Table 2: Squared correlations and Average Variance Extracted (AVE) values						
Variable	**1**	**2**	**3**	**4**	**5**	**6**
1. TMS	**0,611**					
2. Pragmatic boundary	0,060	**0,550**				
3. Semantic boundary	0,070	0,297	**0,570**			
4. Syntactic boundary	0,248	0,109	0,086	**0,512**		
5. Personalized directories	0,076	0,007	0,014	0,078	**0,538**	
6. Codified directories	0,068	0,001	0,000	0,000	0,077	**0,530**

Table shows squared Pearson correlation coefficients for all relationships.

AVE values shown on diagonals.

Results

In order to test the relationships in the theoretical model, structural equation modeling was applied, using AMOS 5.0, which provides Structural Equation Modeling (SEM) and analysis of covariance structures, or causal modeling. While the measurement model (which was discussed above) concerns the validity and reliability of the measurements used, a structural model concerns the causal relations between these measurements. Structural Equation Modeling basically entails the testing of a set of regression equations simultaneously, providing both parametric statistics for each equation and indices that indicate the fit of the model to the original data. The strength and significance of the different hypothesized relationships were therefore tested using AMOS 5.0.

The analysis showed that the model in Figure 1 had an insufficient fit: Chi square was significant (67.7, df=9, $p < 0.001$), and the ratio of the Chi square to the degrees of freedom was 7.5. Since the Chi square value is sensitive to sample size and non-normality, the ratio of Chi square to degrees of freedom is preferred as a fit statistic (Browne and Cudeck 1993). Although different critical values are considered valid for this statistic, values below 3.0 are generally assumed to indicate a sufficient fit, and values below 2.0 a close fit. Furthermore, the relative fit statistics indicated that the model's fit was insufficient as well: although GFI was close to the critical value of 0 .90 at 0.86, CFI and TLI should be close to 1 and scored 0.56 and 0.32, and finally, the Root Mean Square Error of Approximation was 0.21, whereas a value of 0.05 would indicate a close fit, and a value of 0.08 or lower still indicates a reasonable error of approximation.

The modification indices provided by AMOS indicated that the model fit could be significantly improved by adding two relationships between the knowledge boundaries: a direct influence of pragmatic boundaries on both syntactic and semantic boundaries. Of course, one should always be extremely cautious in modifying a model based on modification indices, since this may lead to models that deviate strongly from the theoretical assumptions on which the original model has been built. Since SEM is mainly a confirmatory technique (used for validating theoretical assumptions), modifying a model raises issues in terms of validation. In this case, as we will argue below, these modifications do make theoretical sense and even lead to new insights into the interrelatedness of knowledge boundaries. We address the issue of validation raised by these modifications in the 'Limitations and Future Research' section.

Adding both relationships produced a model that did have a sufficient fit: Chi square (12.5, df=7) was not significant, and the ratio of Chi square to degrees of freedom was 1.8 (indicating a good fit). The relative fit indices indicated a good fit as well: GFI scored 0.97, CFI and TLI scored 0.96 and 0.92. The RMSEA value of 0.07 fell short of a close fit (0.05), but it was well within the range of a satisfactory error of approximation (0.08). All relationships in this model were significant at $p<0.05$. Figure 2 presents the model that resulted from these analyses.

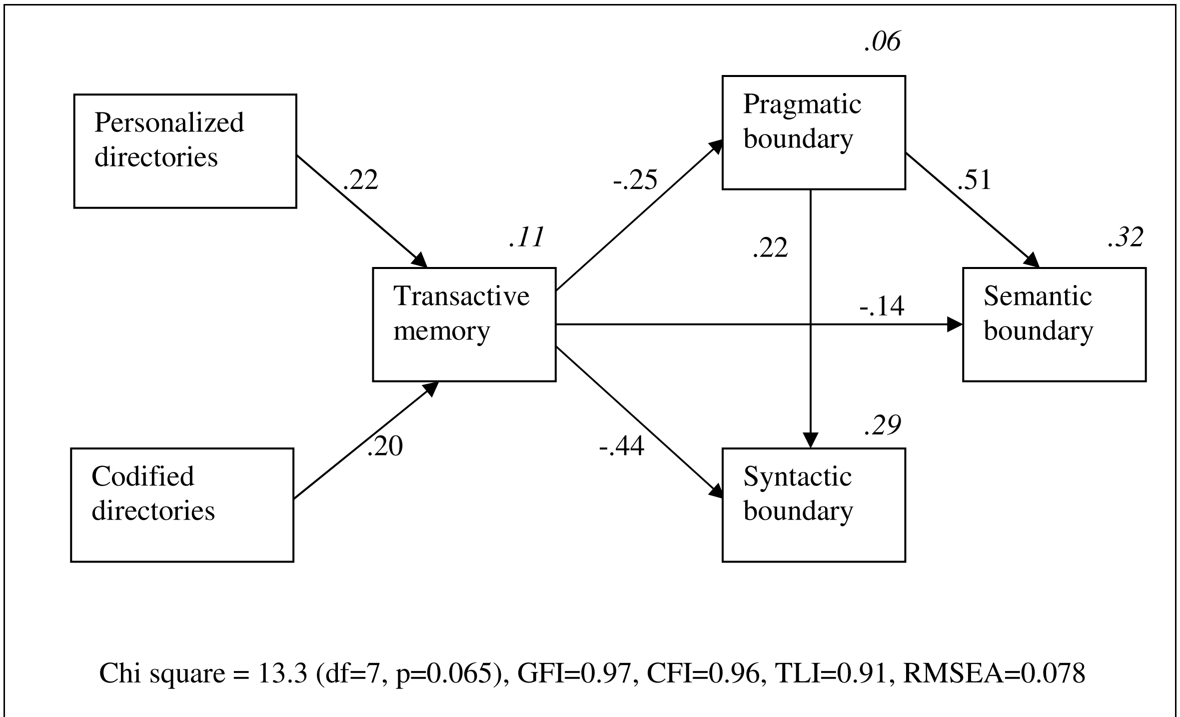

Figure 2. Tested model

The model in Figure 2 provides support for all but one of our hypotheses, and adds some important insights to our theoretical assumptions as well. First, the use of both personalized and codified directories positively influences the existence of a Transactive Memory System, which provides support for both hypotheses 4.1 and 4.2. However, hypothesis 4.3 is rejected because the influence of personalized directories is stronger: a Beta of .22 ($p < .01$) compared to a Beta of .209 ($p < .05$) for the influence of codified directories.

Next, the existence of a TMS indeed has a role in bridging knowledge boundaries: TMS negatively influences the existence of syntactic, semantic and pragmatic boundaries (i.e. it helps to bridge all three knowledge boundaries). This provides support for hypotheses 1, 2 and 3.

We also find, however, an interesting relationship between the different boundaries: the pragmatic boundary positively influences both the syntactic and semantic boundaries. These relationships can be explained by diverging interests (which indicate the existence of the pragmatic boundary) that lead to confusion in terms of a common lexicon (syntactic boundary) and in terms of shared meanings (semantic boundary). This is an important addition to Carlile's (2002) idea that each boundary more or less "builds" on the previous one. Our results suggest that the pragmatic boundary (diverging interests) is not so much a consequence of the syntactic and semantic boundaries, but partly causes these.

Discussion and implications

As mentioned in the previous section, our findings indicate an interesting interrelatedness of the knowledge boundaries. Our results indicate that the existence of a pragmatic knowledge boundary causes semantic and syntactic boundaries. This means that if members of a cross-functional group involved in collaborative work pursue different goals, the knowledge embedded in localized practices and principles on which their (different) goals are based leads to differences in assumptions made by actors and different interpretations of the actions of others (i.e. a semantic boundary). It also leads to the use of different lexicons based on localized knowledge and practices (i.e. a syntactic boundary).

Learning about this influence of a pragmatic boundary on both the syntactic and semantic boundaries adds a new insight to the theory of knowledge boundaries, and is essential for developing understanding of how knowledge boundaries can be bridged. Past research has addressed the bridging of knowledge boundaries following Carlile's (2002) assumption that the pragmatic boundary "builds" on the semantic boundary which, in turn, "builds" on the syntactic boundary. In line with this assumption, the knowledge transfer, translation and transformation processes suggested by Carlile (2004) treat the bridging of knowledge boundaries in a sequence starting from the syntactic boundary (transfer), then the semantic one (translation) and finally the pragmatic boundary (transformation). However, in the light of our results we argue that treating knowledge boundaries in such a sequence will not be effective because as long as a pragmatic boundary exists, it will create additional syntactic and semantic barriers. A more effective way to deal with knowledge boundaries would be to start by putting efforts into bridging the pragmatic boundary in the first place. This, in turn, will trigger the bridging of the syntactic and semantic boundaries. Engaging in practices suggested for bridging the pragmatic boundary, such as trial-and-error problem-solving and the use of boundary objects (e.g. prototypes, diagrams, maps, models and devices) that can be jointly transformed through collective action (Levina and Vaast 2005; Gasson 2006; Kellogg et al. 2006) would introduce (and to some extent enforce) the use of common terminology, templates and procedures between members of cross-functional groups, which, in turn, will help to bridge the syntactic boundary and improve shared understanding (bridging of the semantic boundary).

Our empirical research supported the hypotheses suggesting a relationship between TMS and the bridging of knowledge boundaries. TMS has a direct impact on bridging syntactic, semantic and pragmatic knowledge boundaries. As we explained in the hypotheses section, coding, which is one of the three processes through which TMS is activated (along with storing and retrieval), is based on "codes" (labels) attached to knowledge. A TMS develops as individuals use the same labels to create pointers to the location of knowledge. These labels facilitate the use of a common lexicon, which is imperative for bridging the syntactic knowledge boundary.

The impact of TMS on the semantic knowledge boundary relies on inter-personal relationships between members from different functions and on replicated structures (e.g. ways to store documents in IT-based systems) that help individuals from different functions to find relevant information that may explain differences in interpretations outside their function.

The positive impact of TMS on bridging the pragmatic boundary is based on the development of a collective mind (Yoo and Kanawattanachai 2001) and shared mental models (Brandon and Hollingshead 2004; Mohammed and Dumville 2001), which both develop over time as group members engage in collective actions, as discussed in detail in the section where we develop our hypotheses.

Finally, while hypotheses 4.1 and 4.2, suggesting that the use of codified and personalized directories have a positive impact on the existence of TMS, were supported, the results suggest that personalized directories were more important than codified ones, rejecting hypothesis 4.3. Our hypothesis 4.3 was based on the assumption that in cross-functional settings individuals interact more within their function/unit and less with individuals from other functions/units. In such a situation we expected that their social network would mainly include people from their function/unit, therefore they would need to rely more on codified directories when involved in cross-functional collaboration. Apparently, personal contact is the most effective way of getting insight into who knows what, even across sectoral borders. Related to this may be the lack of organization-wide IT-based systems (e.g. if systems and databases used in different sectors are not integrated) that could serve as codified directories. Repeating this survey in another cross-functional organization in the future would help to clarify these findings.

Theoretical implications

Establishing and empirically validating the relationship between TMS and knowledge boundaries provides an important contribution to Transactive Memory theory as well as to understanding how knowledge boundaries can be bridged. Existing Transactive Memory theory that has been recently applied by IS researchers has developed an in-depth understanding of the antecedents and factors that facilitate the development of TMS (e.g. Moreland and Myaskovsky 2000; Brandon and Hollingshead 2004; Akgun et al. 2005; Chang 2005), and has provided empirical evidence of the positive influence of TMS on performance (e.g. Akgun et al. 2006; Lewis 2004; Lewis et al. 2005; Liang et al. 1995; Ren et al. 2006; Yoo and Kanawattanachai 2001). It is argued that TMS, being a collection of pointers to the location of knowledge, helps to divide the cognitive load between members of a group and coordinate knowledge between them, which leads to better performance. In particular, TMS facilitates the transfer and sharing of knowledge between team members (Majchrzak and Malhotra 2004; Nevo and Wand 2005; Oshri et al. 2008) by connecting knowledge seekers with knowledge sources (which can be a document, an expert of an IT-based system).

However, to our knowledge at the time of writing, TMS researchers have not addressed differences between individuals participating in a group-level TMS. In this research we recognize that there are differences between individuals involved in group work. Organizational, functional, hierarchical, cultural and other differences can be translated into knowledge gaps which create difficulties for collaborative work. By distinguishing between syntactic, semantic and pragmatic knowledge boundaries between individuals involved in cross-functional groups, we have studied the role of TMS in bridging each of these three types of boundaries, which extends the existing Transactive Memory theory.

On the other hand, we have contributed to the knowledge management theory by connecting knowledge boundaries with TMS and empirically validating this relationship. Our findings showing that in cross-functional groups TMS has a negative impact on the syntactic, semantic and pragmatic knowledge boundaries mean that by putting efforts into facilitating the development of TMS in cross-functional groups organizations can reduce knowledge boundaries that members of the groups are experiencing. Furthermore, our finding indicating that the pragmatic knowledge boundary is causing the syntactic and semantic boundaries is an important addition to the existing theory of knowledge boundaries and has practical implications in suggesting that the most efficient way of treating knowledge boundaries is in the following order: first pragmatic, then syntactic and semantic, which will utilize the impact of one type of boundary on another.

Furthermore, our findings have implications for the design, maintenance and suggested use of IT-based systems in organizations. In particular, knowledge about the role TMS plays in bridging knowledge boundaries should be taken into account when organizations implement IT systems, such as KMS, Expertise Management Systems, various document management systems and portals, to ensure that these systems facilitate the use of codified TMS directories by organizational members. For example, the integration of departmental IT-based systems to enable corporate-wide access to codified information would facilitate the use of codified TMS directories and allow members of different functional departments to find relevant documents outside their department or contact details of a needed expert. Corporate-wise IT would also promote the use of a common vocabulary across an entire organization (e.g. commonly used keywords assigned to documents or used to describe areas of expertise of individuals used to store and search for information in organization-wide databases), which in turn would contribute to reducing semantic and syntactic knowledge boundaries. Furthermore, using a standard document folder structure for individual projects (e.g. a standard template for a portal structure) would facilitate a structured and consistent approach to storing and updating documents. Such replicated structures would help individuals to develop shared mental models and find relevant information in the new settings (e.g. when joining a new project team), which could help in understanding the sources of differences in interpretations between individuals (i.e. bridging the semantic boundary). Last but not least, IT could also support bridging of the pragmatic knowledge boundary by providing tools that could be used for engaging in joint work-practices, such as *design tools* (e.g. Computer-Aided Design (CAD) tools or Computer-Aided Software Engineering (CASE) tools), some of which can be used as boundary objects (e.g. prototypes and diagrams), and generic *collaboration technologies*, such as application and desktop sharing and electronic white-boards that facilitate the visualization and sharing of documents between individuals (in particular, when individuals are not co-located which often the case in cross-functional teams).

Finally, while the vast majority of TMS studies are based on students and/or conducted in laboratory settings, as shown by Peltokorpi (2008), our study is one of the few that have been based on real-life subjects and their experience of working together in real-life conditions.

Practical implications

In terms of practical implications, the results of this research could allow practitioners to decide on the most appropriate mechanisms, channels and IT tools for knowledge transfer and sharing to facilitate the bridging of the most critical knowledge boundaries in a specific organizational situation. In particular, any new collaboration should start from identifying knowledge boundaries between the individuals involved. If pragmatic boundaries are identified, they should be treated first: this in turn would facilitate bridging syntactic and semantic boundaries. Development of a group-wide and organization-wide TMS would act as a proactive measure towards bridging knowledge boundaries. For example, as discussed in the previous section, developing a corporate-wide document management system or an expertise directory (e.g. “yellow pages”), would facilitate the development of codified TMS directories organization-wide and the use of a common lexicon. Cross-departmental events and social activities, on the other hand, would facilitate the development of personalized TMS directories.

Limitations and Future Research

A first limitation of this research is that we modified our model based on the outcomes of the analysis. Adding or deleting relationships to or from a model is not uncommon in SEM (in fact, it is the reason modification indices are provided), but it does raise an issue in terms of validation. The basic goal of SEM is to validate a previously defined model, and making changes to this model could be seen as conflicting with that confirmatory goal of this analysis. To cross-validate the model that was the ultimate result of our analysis (including the interrelationships between knowledge boundaries), it should be established whether this model fits new data. Therefore, our first suggestion for future research is to conduct similar studies in other organizations, in order to validate the model that has resulted from our analyses and improve the generalizability of the findings.

Including more organizations in the survey would have provided more external validity and reliability to our results in case the same or comparable results occurred when we applied a *replication logic*, which means that a theory is tested through the process of replicating the results of a first case study in subsequent case studies. If different results should occur, these must be explained by the theory in order for the replication logic to hold (Yin 1994).

To address these limitations we plan to extend this research further to include more organizations in the survey, and to combine it with qualitative data by interviewing representatives from different functions in order to understand more in depth the nature of the knowledge boundaries they face and the way they use TMS. To investigate further the relative roles of personalized and codified directories in bridging knowledge boundaries we intend to pay specific attention to the IT infrastructure of organizations included in the study. It is possible that the relative roles of codified and personalized directories are company-dependent. For example, it is possible that large IT consultancy firms that adopt a codification knowledge approach (Hansen et al. 1999) rely more on codified directories while other types of firms that offer highly customized solutions rely more on personalized directories.

Further suggestions for future research would include conducting network analysis and adopting a longitudinal approach to establish causality.

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