THE ROLE OF A TRANSACTIVE MEMORY SYSTEM IN BRIDGING KNOWLEDGE BOUNDARIES

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BACKGROUND AND MOTIVATION

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 (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, the various contexts and circumstances in which different organizational departments operate (Carlile 2002; Carlile 2004), 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 of excellence that support knowledge sharing (e.g. Oshri et al. 2007; Kotlarsky et al. 2008), inter-personal ties (Kanawattanachai and Yoo 2002; Ahuja and Galvin 2003), trust (Jarvenpaa and Leidner 1999; Ridings et al. 2002), transactive memory systems (Nevo and Wand 2005; Oshri et al. 2008), formal interventions that facilitate knowledge integration in groups (Okhuysen and Eisenhardt 2002), 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 2002).

The paper is organized as follows. The next section discusses knowledge boundaries and 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 itfrom 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). 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 different origins, such as limitations in information processing (Lawrence and Lorsch 1967; Galbraith 1973), 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 (and how) they accomplish their part of the work. 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 ta process that requires knowledge integration make assumptions, often unconsciously, which are not obvious and can even contradict others' assumptions. Carlile (2002) refers to 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; Levina and Vaast 2005; Kellogg et al. 2006).

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 recognizes 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 transforming 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 (Levina and Vaast 2005; Gasson 2006; Kellogg et al. 2006). 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 (e.g. Carlile 2002; Carlile 2004; Scarbrough et al. 2004), as well as more novel post-bureaucratic organizational forms (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 facilitating innovation and collaborative work. For example, Scarbrough et al. (2004) studied learning between projects in project-based organizations where project autonomy presents 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 a 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 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 recommended for bridging knowledge boundaries suggested 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. Teigland and Wasko 2003; Levina 2005; Levina and Vaast 2005; Pawlowski and Robey 2005; Santos and Eisenhardt 2005; Espinosa et al. 2006; Gasson 2006; Lindgren et al. 2008). Boundary-spanning practices discussed in this literature include boundary objects that comprise *artifacts* such as physical product prototypes, designs in various forms (e.g. drawings, blueprints, sketches), shared 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 knowledge boundaries, 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 by applying a Transactive Memory System, a subject recently receiving significant attention in the knowledge management, group behavior and product development literature, where it has been discussed in relation to collaborative work (e.g. Lewis 2004; Nevo and Wand 2005; Ren et al. 2006; Jarvenpaa and Majchrzak 2008), learning (e.g. Yoo and Kanawattanachai 2001; Lewis et al. 2005; Akgun et al. 2006) and knowledge transfer (e.g. Oshri et al. 2008). This perspective is complementary to the existing views on knowledge boundaries that so far has been embedded in the literature on boundaries and boundary-spanning. In the following section we introduce the concept of Transactive Memory System followed by a discussion of its role in bridging knowledge boundaries.

A 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. Yoo and Kanawattanachai 2001; Lewis 2004; Lewis et al. 2005; Akgun et al. 2006) or have focused on antecedents and factors that facilitate development of TMS (e.g. Moreland and Myaskovsky 2000; Brandon and Hollingshead 2004; Akgun et al. 2005; Chang 2005). 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 a facilitator of transferring and sharing knowledge between team members (Majchrzak and Malhotra 2004; Nevo and Wand 2005; Oshri et al. 2008).

In practice, the development and activation of core TMS processes (coding, storing and retrieving) is supported by codified and personalized directories (Oshri et al. 2008), as illustrated in Table 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) 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. databases) 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).

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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, 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 area 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, 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) 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 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 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 conflicts (e.g. Panteli and Sockalingam 2005). Therefore, knowing “who knows what” and using interpersonal channels to find a 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, aTMS 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 “semistructures” that embody rules to help group members to organize their knowledge integration processes in a flexible manner would help reveal differences in interpretations that are the source of the syntactic knowledge boundary and, 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 shared mental models (Brandon and Hollingshead 2004), 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 TMS directories available for members of cross-functional groups embrace corporate-wise document management systems, portals and "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 to knowledge outside their department. Thus we hypothesize:

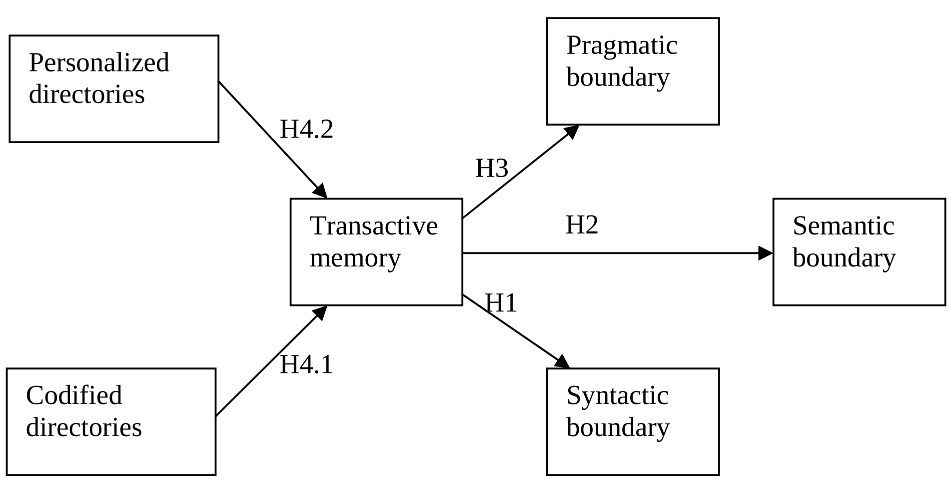
H4.1: In cross-functional groups the use of codified directories will positively influence the existence of TMS

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 that of personalized directories (H4.3).

METHODOLOGY

In order to test the theoretical model, a survey study was conducted within a Dutch governmental organization. The focus of the survey was on collaboration and knowledge sharing between the different sectors in this organization, which were all 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 created 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 at various locations.

The questionnaire was designed to measure each of the concepts included in the theoretical model. The relevant variables were all measured using 5-point Likert scales. The scale for Transactive Memory System was based on the work of Lewis (2003) and consisted of five items, such as “I know which people from different sectors have expertise in specific areas”. Thus, 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 . An example of an item for the syntactic boundary scale is “I often find it difficult to understand the jargon used by colleagues in other sectors”. An example of an item used to measure the semantic boundary is “When I collaborate with people from other sectors, we often have different interpretations of the meaning of things”. The pragmatic boundary was measured by statements such as “When I collaborate with people from other sectors, we often need to modify our existing points of view in order to come to a solution”. The scales for codified and personalized directories consisted of items measuring the extent to which different instruments were used by teach respondent to share knowledge: instruments like brainstorming, collaborating, mentoring and coaching for personalized directories, and instruments like the intranet, documents and websites for codified directories. Table 1 presents the descriptives, correlations and Cronbach’s alphas for the variables in the theoretical model.

Table 1. Descriptives, correlations and reliabilities for scales used in survey

Variable	Mean	SD	1	2	3	4	5	6
1. TMS	3.14	0.63	**0.75**					
2. syntactic boundary	2.82	0.57	-0.59**	**0.68**				
3. semantic boundary	2.86	0.58	-0.35**	0.47**	**0.68**			
4. pragmatic boundary	2.88	0.47	-0.35**	0.44**	0.59**	**0.60**		
5. personalized directories	3.14	0.56	0.36**	-0.28**	-0.18*	-0.16	**0.75**	
6. codified directories	3.41	0.81	0.29**	-0.04	-0.01	-0.01	0.41**	**0.82**

Table shows Pearson correlation coefficients for all relationships. Significance indicated by:
* p <.05; ** p < .01;
Cronbach's alpha shown on diagonals.

Table 2 shows that the scales for TMS, personalized directories and codified directories all have a satisfactory reliability, with Cronbach's alpha values of .75 or higher. For the boundary scales, the syntactic and semantic boundary/ies? approach a satisfactory reliability with alphas of just below .70, but the pragmatic boundary scale falls short of this criterion with an alpha of .60. However, since the knowledge boundary scales are newly developed ones, they have an exploratory nature in the sense that they serve the purpose of designing new measures. For exploratory research, .60 is the lowest boundary for Cronbach's alpha (Hair et al. 2006). Consequently, the alpha values for all three knowledge boundaries are judged to be acceptable for this study, but in our discussion section we will emphasize the need for a continued search for better measurements for these variables.

In order to test the theoretical model in Figure 1, structural equation modeling was applied. We used AMOS, 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. Based on such statistics, models can be adjusted in terms of adding or deleting relationships – in line with theory, of course. AMOS was used to test the model that was presented in Figure 1 in terms of the strength and significance of the different hypothesized relationships, as well as in terms of the fit of this model to the covariances found in the data.

RESULTS

The model in Figure 1 produced problematic results in terms of model fit: Chi square was significant (81.8, df=9, p <.001), and more importantly, the ratio of the Chi square to the degrees of freedom was 9.1. 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 the fit statistic (Marsh and Hocevar 1985). Although different critical values are maintained for this statistic, values below 3.0 are generally assumed to indicate a sufficient fit. The Adjusted Goodness of Fit Index (AGFI) was well below the critical value of .90 at .62, and the Tucker-Lewis Index should be close to 1 and scored .45, so both these indices would indicate an insufficient fit. Moreover, the Root

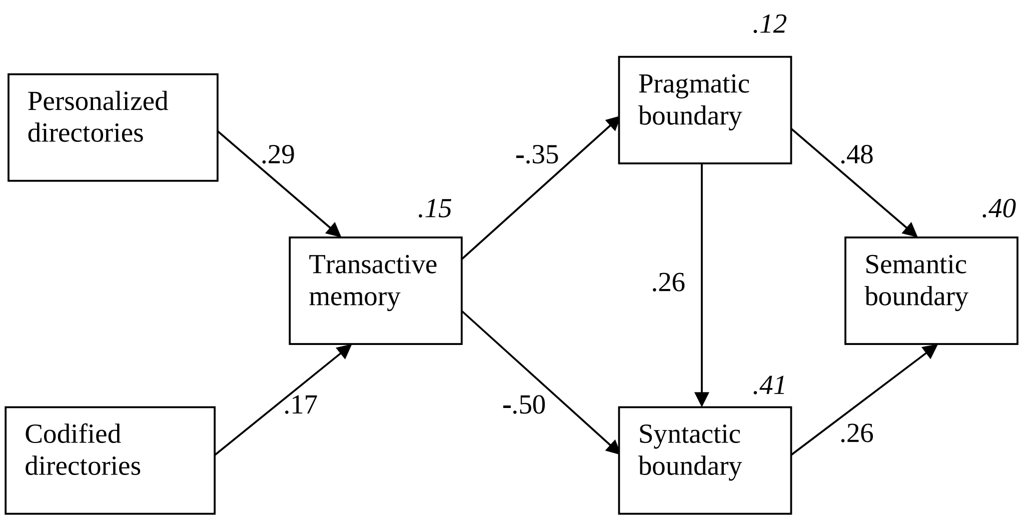
Mean Square Error of Approximation scored .23, whereas an RMSEA value of .05 would indicate a close fit, and a value of .08 or lower would still indicate a "reasonable error of approximation" (Browne and Cudeck 1993). These fit statistics lead to the conclusion that the model in Figure 1 should be rejected.

The modification indices provided by AMOS strongly indicated that the knowledge boundaries were interrelated, and that adding these interrelations would improve the model fit. 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 was built. 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. So, based on the modification indices, the following relationships were added to the model:

- the pragmatic knowledge boundary influences both the semantic and the syntactic knowledge boundaries, and
- the syntactic knowledge boundary influences the semantic boundary.

Adding these relationships to the model strongly improved the fit statistics, but also meant that the direct relationship between TMS and semantic boundary became non-significant. Ultimately, the model emerged that is presented in Figure 2. This model meets the criteria for fit statistics: Chi square is not significant (9.2, df=7, p>.05), the ratio of Chi square to degrees of freedom is below 3 (and even 2) at 1.3, AGFI (.94) and TLI (.98) are both well above .90 and approach 1, and RMSEA (.046) is below .05. In the model, the figures near the arrows indicate strength of relationships (from -1 to 1) and the figures above endogenous variables indicate proportion of explained variance.

Figure 2. Tested model



chi square = 9,204 (df=7, p=,238), AGFI=,942, TLI=,979, RMSEA=,046

The model in Figure 2 provides support for a number 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 .29 ($p < .001$) compared to a Beta of .17 ($p < .05$) for the influence of codified directories.

Next, the existence of a TMS indeed has a role in bridging knowledge boundaries: TMS negatively influences both syntactic and pragmatic boundaries (i.e. it helps to bridge syntactic and pragmatic boundaries). This provides support for hypotheses 1 and 3. The existence of a TMS is not significantly directly related to semantic boundaries, though, rejecting hypothesis 2.

We do find, however, an interesting interrelatedness between the different boundaries. First, 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 pragmatic boundaries (diverging interests) are not so much a consequence of syntactic and semantic boundaries, but partly *cause* these. Secondly, the syntactic boundary positively influences the semantic boundaries: confusion in terms of a common lexicon leads to confusion in terms of shared meanings. This is in line with Carlile's idea of the interrelatedness of these boundaries. So, in conclusion, TMS does have an influence on semantic boundary as well, but this is an indirect influence, via the other two boundaries.

DISCUSSION AND IMPLICATIONS

As mentioned in the previous section, our findings indicate an interesting inter-relatedness of the knowledge boundaries. First, the positive influence of the syntactic boundary on the semantic boundary, which is in line with Carlile (2002, 2004), implies that members of cross-functional teams that use different terminology, templates and other means to express themselves are more likely to create different interpretations of issues presented or documents created by their group-mates belonging to another function, i.e. face a semantic knowledge boundary. Assumptions made by each member of a group and the meanings constructed based on these assumptions are triggered by associations between terms (vocabulary), templates and diagrams used by other members of the group that relate to the specific mental models of individuals participating in group work. Therefore the use of a common lexicon, templates and other means of articulation are more likely to create similar associations among members of cross-functional groups.

Second, 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. semantic boundary). It also leads to the use of different lexicons based on localized knowledge and practices (i.e. 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 a syntactic boundary (transfer), then a semantic one (translation) and finally a 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 bridging the pragmatic boundary. Engaging in practices suggested for bridging pragmatic boundaries, 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 the relationship between TMS and the bridging of knowledge boundaries. TMS has a direct impact on bridging pragmatic and syntactic boundaries and an indirect impact (through the pragmatic boundary) on the semantic boundary. 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 positive impact of TMS on bridging pragmatic boundaries is based on the development of a collective mind (Yoo and Kanawattanachai 2001) and shared mental models (Brandon and Hollingshead 2004), which both develop over time as group members engage in collective actions, as discussed in detail in the section where we develop our hypotheses.

It is interesting that TMS only has an indirect impact on bridging semantic knowledge boundaries. Our argument was that introducing replicated structures (e.g. ways to store documents) in the entire organization would help individuals find relevant information that may explain differences in interpretations outside their function. Such structures would be part of codified directories. However, as our hypothesis regarding the relative importance of codified and personalized directories (H4.3) was not supported, this implies that in the organization where we conducted a survey TMS relied to a greater extent on personalized directories rather than on codified directories. The fact that codified directories were used less than personalized ones might mean that codified structures that could support shared understanding were not activated. Repeating this survey in another cross-functional organization in the future would help to clarify these findings. On the other hand, if indeed, regardless of the directories used, TMS has only an indirect impact on bridging semantic boundaries, then efforts at bridging knowledge boundaries should focus on bridging pragmatic boundaries in the first place. This, in turn, will trigger bridging of syntactic and semantic boundaries.

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 systems (e.g. if systems and databases used in different sectors are not integrated) that could serve as codified directories.

Theoretical Implications

Establishing and empirically validating the relationship between TMS and knowledge boundaries provides an important contribution to TMS theory as well as to understanding *how* knowledge boundaries can be bridged. Existing TMS theory has developed an in-depth understanding of 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. Yoo and Kanawattanachai 2001; Lewis 2004; Lewis et al. 2005; Akgun et al. 2006). 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, a system or an expert). However, to our knowledge at the time of this 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 studied the role of TMS in bridging each of these three types of boundaries, which extends the existing TMS theory.

On the other hand, we have contributed to the theory of knowledge boundaries by connecting it with TMS and empirically validating this relationship. 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 only then semantic, which will utilize the impact of one type of boundary on another.

Practical Implications

In terms of practical implications, the results of this research could allow practitioners to decide on the most appropriate mechanisms and channels 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, developing a corporate-wide document management systemor 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

The research presented in this paper is based on a survey conducted in one organization. Including more organizations in the survey would provide more external validity and reliability to our results (Yin 1994).

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 to understand more in depth the nature of the knowledge boundaries they face and the way they use TMS.

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

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