

Measurement of team knowledge: transactive memory system and team mental models

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Abstract — The paper addresses an issue of measurement of team knowledge. Different, though related, views on team knowledge, namely transactive memory system and team mental models, are discussed. Transactive memory system is a concept of a group memory. It consists of individual expertise of team members as well as their knowledge of “who knows what” and is based on communication. Team mental model is a shared organized understanding of team’s environment. The emphasis in the paper is given to measurement of transactive memory system. Research on team mental models is considered as supplementary. Reviews of approaches to measurement of team knowledge as well as research to date on transactive memory system in organizational settings are presented. An example that reveals contradiction between results of measurement of transactive memory system and team mental model is provided. The paper finishes with the discussion of research gaps identified in the literature and discovered in the example presented.

Keywords — team knowledge, measurement, transactive memory system, team mental model.

I. INTRODUCTION

Teams play important role in modern economy [1]-[4]. Common goals and interdependence of the members distinguish teams from other organizational units such as groups. The interdependence and need to accomplish tasks collectively are both a curse and a blessing. On the one hand, teams can accomplish tasks that require competence which is beyond abilities of any individual. On the other hand, experts in different areas may experience difficulties with understanding each other [5]. Thus there is a need in studying teams in general and team knowledge in particular in order to improve their performance.

Number of publications on knowledge management has grown recently. Knowledge measurement, though less discussed in the literature, is an essential part of knowledge management, because one cannot manage what cannot be measured. However, intangible and multifaceted nature of knowledge makes its measurement difficult. This paper addresses a tricky question of knowledge measurement by discussing two team-level concepts: transactive memory system and team mental models. Transactive memory system is a concept of a group memory that consists of individuals’ knowledge, knowledge of “who knows what” in the team and is based on communication. A team mental model is defined as organized shared understanding of

knowledge relevant to team performance. Transactive memory system stresses heterogeneity of teammates’ task-related knowledge whereas research on team mental models emphasizes homogeneity. Both concepts reflect some (though, not all) facets of team knowledge, and both are said to have positive impact on team’s performance. Primary emphasis in this paper is given to transactive memory system; research on team mental models is considered as supplementary.

The paper discusses current state and identifies research gaps and problems in measurement of transactive memory system in real organizational teams. The outline of the paper is as follows. First, team knowledge and, specifically, concepts of transactive memory system and team mental models are described. Then general approaches to measurement of team knowledge are discussed and a review of the studies on transactive memory system in organizational settings is presented where existing approaches to its measurement are assessed along several dimensions. Measurement of team knowledge is illustrated by measurement of transactive memory system and team mental model in a distributed team. Contradictory results obtained with different measurement scales indicate that application of some measurement approaches to distributed organizational teams requires caution. The paper finishes with the discussion of the research gaps identified in literature review and discovered in given example.

II. TEAM KNOWLEDGE

A. General considerations

Research on team knowledge belongs to a stream of research on group cognition [6], [7]. A group is a broader concept than a team: while all teams are groups, not all groups are teams because, unlike in teams, members of a group may not have common tasks [6]. A general assumption of research on group cognition is that group knowledge is more than the sum of group members’ knowledge. Researchers agree on its multifaceted nature [7], [8], but hold different, though related, views on how it should be explained.

B. Transactive memory system as team knowledge

To describe team knowledge Fulk et al. [9] use the term “knowledge resource structure” which refers to distribution of knowledge resources across locations, team members and data repositories, as well as knowledge sharing processes that allow to achieve such distribution.

Knowledge resource structures are described by the extent of centralization and the degree of redundancy. The extent of centralization denotes knowledge location: it may reside in one person or repository, or, alternatively, several (or all) team members may possess it. Degree of redundancy describes the content of knowledge resource structure. Situations when everyone knows the same things are examples of total redundancy. The opposite ones are that of differentiation, i.e. team members are experts in different areas. To explain knowledge resource structures Fulk et al. [9] use a theory of transactive memory.

A theory of transactive memory was developed by Wegner [10]-[12]. It evolved out of the observation that people may, instead of memorizing information themselves, use others as memory aids. Wegner defines transactive memory system as “a set of individual memory systems in combination with the communication that takes place between individuals” [10]. Individual memory systems, in which information on individual areas of expertise as well as knowledge on “who knows what” are stored, constitute a structural (“knowledge”) component of transactive memory system. Communication processes among group members constitute a process component. According to Wegner [11], these components distinguish transactive memory system from a concept of group mind because in the former thought processes are easily observable and communication is taken into account.

Transactive memory system is not imposed on a group. It develops over time. At the early stages of group existence the expertise judgments may be based on stereotypes. Since these judgments are often erroneous, transactive memory systems in such groups are poor. When people stay together for a longer time, they learn each other better and expertise judgments become more accurate. Transactive memory system is said to be developed when group members possess different expertise, are accurate in recognition of expertise of the others and can freely communicate to combine their expertise when necessary. Advantages of a developed transactive memory system are two-fold. On the one hand, it allows group members to reduce individual information burden by dividing cognitive labor. On the other hand, since people in a group are experts in different areas, they may provide answers to questions that are far beyond their individual expertise. Mohammed and Dumville [8] note that the theory of transactive memory has been developed for groups; however, nothing precludes its application to teams.

C. Team mental model as team knowledge

Cooke et al. [7] use different approach to explain team knowledge and define it “as the collection of task- and team-related knowledge held by teammates and their collective understanding of current situation” (fig. 1). Task- (e.g. expertise in a certain area) and team-related knowledge (e.g. understanding of task procedures and knowledge of what teammates know) comprise team mental model. Collective understandings of the current situation are called team situation model. The former is static; the latter is fluid. Team situation model builds on

team mental model but, unlike the latter, incorporates characteristics of the current situation. Team situation model is not yet well conceptualized and new methods are needed to approach its measurement [7]. Thus, the following discussion is limited to team mental models only.

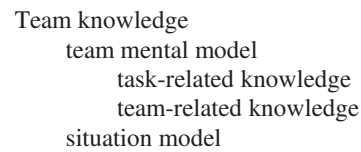


Figure 1. Team knowledge according to Cooke et al. [7].

Team mental model “refers to an organized understanding of relevant knowledge that is shared by team members” [8]. Klimoski and Mohammed [6] stress that it is a construct, not a metaphor, and it allows to capture a real life phenomenon. Discussion of team mental models often revolves around their content, form and function.

A content of team mental models can be grouped into knowledge related to situations (what goes on with a team including mental representations of equipment, knowledge of others, environment, etc.) and knowledge related to actions (what to do about those situations, for example behavioral routines for action) [6]. Alternatively, four content domains can also be recognized [1], [13], [14]:

- equipment model (equipment-related knowledge);
- task mental model (task-related knowledge);
- team member mental model (team members-related knowledge, including “who knows what”)
- teamwork schema (process-related knowledge).

A form of a team mental model refers to the fact that a mental model is not any but organized knowledge [1], [14]. Meaningful patterns of organized knowledge can be, for example, cause-effect relationships or categorical membership [6].

In connection with the function, it is said that shared mental models improve team performance. There is no clarity, though, on the meaning of the word “shared”. It can mean (a) identical (having in common) knowledge; (b) “divided” or “distributed among team members” (individuals possess different knowledge; no overlap); (c) overlapping knowledge (some of the knowledge is different, some is held in common) [1], [6], [7]. Though researchers are generally vague in specifying what the term “shared” means [6], most of the studies are focused on measuring homogeneity of mental models held by individual team members. The general thesis of team mental model research is that knowledge held in common improves team performance.

D. Relationship between transactive memory system and team mental models

Though team mental models and transactive memory system are different concepts, Mohammed and Dumville [8] notice that research streams on both concepts can benefit from cross-fertilization. Transactive memory system

concept stresses heterogeneity in relation to task-related expertise possessed by team members; team mental models emphasize homogeneity of any part of the whole spectrum of knowledge (not only task-related).

Both knowledge heterogeneity and knowledge homogeneity are important for team performance. On the one hand, knowledge heterogeneity is important because teams are created specifically to fulfill tasks that a single individual can not accomplish [7]. On the other hand, teammates require some shared knowledge as well in order to be able to understand each other: "overlapping teamwork knowledge is necessary to provide adequate coordination" [8]. However, totally overlapping knowledge makes teams dysfunctional: it leads to sing-minded view on tasks, so called "groupthink" [1], [15]. Thus, it can be suggested that for successful team performance heterogeneity of task-related and homogeneity team-related knowledge are required.

Heterogeneity and homogeneity, both are present in the structural component of transactive memory system. Differentiation of individual expertise describes heterogeneity of task-related knowledge while awareness of "who knows what" represents homogeneity of team-related knowledge (cf. [1]). Research on team mental models may assist in measuring structural component of transactive memory system, especially its homogeneous constituent [16], [17]. Similarly, team mental models research can benefit from the studies on transactive memory system by examining techniques for measuring heterogeneity [8].

III. MEASUREMENT OF TEAM KNOWLEDGE

A. General considerations

Measurement of team knowledge is not a trivial task. Firstly, its multifaceted nature prevents emergence of a uniform measure. Moreover, different measurement targets (e.g. homogeneity vs. heterogeneity) call for different measures [7]. Furthermore, Mohammed et al. [14] mention, with regard to mental models, that a choice between different mental models that one wants to study is, actually, determined by the nature of a team's cognitive task. Generally, researchers agree that the lack of parsimony in conceptual development of team mental models precludes development of empirical research on the topic. This can be fully applied to team knowledge in general as well since, at least according to some conceptualizations, team mental models can be conceived of as representations of team knowledge [7].

To complicate things further, there is also confusion over how to measure group-level cognitive phenomena [7], [8], [14]. Klimoski and Mohammed [6], when talking about mental models, note that measurement at the group level is "complex and problematic". Generally, two basic approaches to measurement of group-level phenomena are recognized: collective and holistic [7], [14].

According to collective approach, individual measures are aggregated into a group-level measure. Individual measures can be collected during observations, interviews

and surveys or by using other methods [7]. This approach is easily feasible and most of the research to date uses aggregation. However it underestimates the importance of team members' interactions [7] and simplifies relationships within a team assuming that every member's contribution to team knowledge is of equal importance [14].

Holistic approach appreciates importance of team process behaviors and treats a group (or a team) as a whole, allowing collectivity to "speak for itself" [14]. Observations of group's performance or interviewing of key informants are possible group-level techniques [14]. However researchers agree that there is a need to develop new holistic measurement methods [7].

Approaches to measurement of team knowledge can also be divided into direct and indirect [16]. If it can be said in advance what knowledge is required for a team to fulfill a certain task and a cognitive content of a study is provided by researchers [14], a measurement approach is called direct. While this is feasible for certain types of tasks (e.g., well structured tasks, like in aviation team example in [7]), it may be difficult for tasks of high complexity and uncertainty (complex R&D projects aimed at development of new knowledge). To overcome this problem, team members can be asked to provide cognitive content by themselves. However, in this case a difficulty lies in interpreting peculiar responses [14]. Furthermore, task specificity of direct measures precludes either comparison between different cases or quantitative research in field settings [16]. Alternatively, it is possible to measure manifestations of a studied construct. Manifestations are indirect behavioral measures that allow to detect existence of a studied construct [18]. Approaches that are aimed at measurement manifestations of constructs are called indirect and generally recommended for measuring conceptual abstractions [19].

Given complexity of the nature of team knowledge and approaches to its measurement, the best tactics is to focus on a particular research question and look at how different viewpoints and techniques may help to answer it [7], [14]. Following this line, this paper focuses solely on the measurement of team knowledge in the form of transactive memory system in organizational settings and looks at how research on team mental models can support studies in this area.

B. Review of measurement approaches to transactive memory system in organizational settings

Research on transactive memory systems in real organizations is scarce. Tables 1 and 2 present a summary of the studies conducted on the topic to date. From a brief overview it is clear that these studies differ in terms of both measurement approaches and content (i.e. interpretation of transactive memory system).

Though all the studies refer to works of Wegner as a founder of transactive memory theory, transactive memory system is defined in these studies in different ways (table 1).

TABLE 1
A LIST OF STUDIES ON TRANSACTIVE MEMORY SYSTEM IN ORGANIZATIONAL SETTINGS

Authors	Type of a team	Definition of transactive memory system
Rau [20]	Top management team	"Transactive memory is the set of knowledge possessed by members of the team, combined with an awareness of who knows what within the team"
Rau [21]	Top management team	"Transactive memory is the set of knowledge possessed by the members of a team, combined with an awareness of who knows what within the team"
Austin [17]	Continuing groups	"Wegner's definition of transactive memory includes two parts: (a) a combination of individual knowledge and (b) interpersonal awareness of others' knowledge."
Lewis [16]	Consulting teams; teams in high-technology companies	"Transactive memory ... consists of metaknowledge about what another person knows, combined with the body of knowledge resulting from that understanding. ... A transactive memory system describes the active use of transactive memory by two or more people to cooperatively store, retrieve, and communicate information".
Yoo and Kanawattanachai [22]	Virtual team	"...transactive memory system is the team members' meta-knowledge about who knows what in the team"
Akgün, Byrne, Keskin, Lynn, & Imamoglu [23]	New product development team	"...a TMS consists of the memory stores of particular individuals and any social interactions in which they participate"
Akgün, Byrne, Keskin, & Lynn [24]	New product development team	"... a TMS depicts the "awareness of who knows what in a group"

TABLE 2
CHARACTERISTICS OF MEASUREMENT APPROACHES

Authors	Direct/indirect	Data collection	Aggregated/holistic	Number of dimensions	What was measured	Measurement of awareness (complexity, accuracy, agreement)
Rau [20]	Direct	Questionnaires	Aggregated	2	(1) knowledge possessed by team members; (2) awareness of "who knows what"	Agreement
Rau [21]	Combination	Questionnaires	Aggregated	2	(1) composition of expertise (diversity and depth) (2) awareness of :who knows what"	Agreement
Austin [17]	Combination	Questionnaires	Aggregated	4	(1) knowledge stock (combination of individual knowledge) (2) consensus about knowledge sources (agreement (3) specialization of expertise (4) accuracy of knowledge identification	Accuracy, agreement
Lewis [16]	Indirect	Questionnaires	Aggregated	3	(1) specialization (2) credibility (3) coordination	
Yoo and Kanawattanachai [22]	Indirect	Questionnaires	Aggregation	1	awareness of "who knows what"	Agreement
Akgün, Byrne, Keskin, Lynn, & Imamoglu [23]	Indirect	Questionnaires	Aggregation	3	The same as in Lewis [16]	
Akgün, Byrne, Keskin, & Lynn [24]	Indirect	Questionnaires	Aggregation	1	The same as in Yoo and Kanawattanachai [22]	

Some researchers talk about two dimensions (individual expertise and knowledge of "who knows what") while others use only one dimension (awareness of "who knows what"). The latter are conceptually very close to research on team mental models. In these "one-dimensional" studies the focus is on agreement of recognition of the expertise of the others (table 2). At the same time, Moreland [18] identified altogether three aspects of the awareness constituent of transactive memory system. They are (1) complexity (how detailed knowledge about "who knows what" is), (2) accuracy of the recognition of the expertise of the others, (3) agreement about expertise of the others.

Accuracy is measured in only one study [17]; complexity in the reviewed studies has not been addressed at all.

All the studies use aggregation method for measurement of transactive memory system. Most of them employ indirect measures or a combination of direct and indirect approaches (table 2). With regard to indirect measures, Lewis [16] has developed a 15-item scale based on three manifestations of transactive memory system identified by Moreland and colleagues [18], [25], [26]. These manifestations are (1) differentiation (how different task-related knowledge possessed by teammates is), (2) credibility (how deeply team members trust each other)

and (3) effective coordination. The scale developed by Lewis [16] is not the only one indirect measure used by researchers (cf. [22]), but the only one that undergone thorough validation.

Lack of parsimony in definitions and measurement approaches precludes development of empirical research on transactive memory system. To illustrate the difficulty of its measurement in organizational setting, results of a pilot study are presented in the next section. These results reveal a contradiction between two different measurement approaches.

C. Example of team knowledge measurement in a distributed team

This example is a part of a larger doctoral research project described in detail in Kitaygorodskaya et al. [27]. The studied team consisted of eight people. Its members were physically distributed. The study was undertaken at the final stage of the project. Tenure differences were assumed to be negligible. To measure team knowledge, two approaches were used. Transactive memory system was measured with the indirect scale (“specialization-credibility-coordination”) developed by Lewis [16]. Team mental model, namely awareness of “who knows what”, was measured by checking for agreement of teammates reports on expertise of the others [16], [20].

Results of the measurement of transactive memory system with Lewis’s scale indicated that transactive memory system was developed more than average (specialization score was 3,9; credibility was 3,5; coordination was 3,4 (all the scores are arithmetical means)). Given that, it might have been expected that team members would have had little difficulty in reporting on others’ expertise. However it was not the case. Only three out of eight team members could identify expertise of the others. The rest ones either didn’t answer the question at all or identified expertise of only one or two members. This result is surprising because Lewis [16], when developing the scale, conducted similar analysis in test groups and results of measurement of transactive memory system and awareness of others’ expertise converged. Thus, results of the presented study have revealed controversy between results of measurement of transactive memory system with the scale developed by Lewis [16] and awareness of “who knows what” in the examined organizational setting. Possible explanations include influence of centralized communication network in the team and lack of face-to-face communication due to physical distance. This controversy points also to the fact that researchers should be careful in taking existing scales and applying them blindly to all organizational settings.

IV. DISCUSSION AND CONCLUSIONS

In this paper, a review of literature on team knowledge and its measurement in general and transactive memory system in particular is presented. Research on team mental models is considered as supplementary. Building on this review, following gaps and directions for future research on

measurement of team knowledge in the form of transactive memory system are identified:

- (1) there is a need to come to an agreement on how to conceptualize transactive memory system for measurement purposes. It seems that measuring solely awareness of “who knows what” reflects only one aspect of transactive memory system while what actually team members know and how this knowledge is differentiated do not receive proper attention;
- (2) all of the studies used aggregation approach to measurement of transactive memory system. While it is the easiest way to date to measure group-level phenomenon, it is necessary to develop holistic approaches that will treat a team as a whole;
- (3) given importance of awareness of “who knows what” for transactive memory system, there is a need to pay more attention to its two other characteristics: accuracy and complexity. So far only agreement between team members on expertise recognition is measured in all the studies. However, agreement by itself may be not enough: individuals may agree on the recognition of the expertise of the others but be inaccurate in that. Such agreement may make a team dysfunctional [7];
- (4) furthermore, since awareness of “who knows what” is one of the team mental models that represent *organized* understandings, it would be useful for the purposes of research on transactive memory system to develop measurement approaches that will allow to map “who knows what” in a group. Similarly, Mohammed et al. [14] note that a good measure should provide a mechanism for both elicitation of a mental model content and representation of how these components are connected (structure of mental model). Visual representation of knowledge distribution in a team may be of practical value and help managers to better assess knowledge abilities of the team;
- (5) application of existing measurement scales to different organizational settings requires caution. Controversy between results of two measurements illustrated by the example indicates that more studies are needed to fully understand the phenomenon and calls for more research on indirect measures in diverse organizational settings.

The contributions of the paper are as follows. First, different conceptualizations of team knowledge, scattered before across different sources, are described. Second, approaches to measurement of knowledge on a team level and problems associated with it are discussed. Third, a review of empirical research to date on transactive memory system in organizational settings as well as an example of team knowledge measurement is presented. The example illustrates a controversy between results of two measurements. Building on the literature review and discovered controversy, gaps and directions for future research are presented.

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