# Context-Sensitive Sharedness Criteria for Teamwork (Extended Abstract)

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## ABSTRACT

Teamwork between humans and intelligent systems gains importance with the maturing of agent and robot technology. In the social sciences, sharedness of mental models is used to explain and understand teamwork. To use this concept for developing teams that include agents, we propose context-sensitive sharedness criteria. These criteria specify how much, what, and among whom knowledge in a team should be shared.

## Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence.

## Keywords

Human-Agent Teamwork, Team Mental Models, Shared Mental Models, Sharedness Criteria, Context-Sensitivity.

## 1. INTRODUCTION

Human teamwork has been studied extensively in the social sciences [3,7,8]. In that field, the concepts of team mental models and shared mental models are used to explain and understand teamwork [1]. Team mental models are the mental models that team members have of their team, which includes the context in which they operate, of their fellow team members, of the team task, and team work. Team members who share similar mental models can anticipate each other's responses and coordinate effectively. Shared mental models thus help describe, explain and predict the behavior of the team, and thus allow team members to align their own actions with the expected behavior of others to improve team performance.

Teamwork is also studied in the field of agent technology [2,5,10]. This research involves both teams with only intelligent software agents, and mixed teams with humans and agents [9]. We believe that the team mental model concept developed for human teams is also useful for understanding and predicting the performance of teams with agents. Understanding the relation between team mental models and team performance allows to design agents that have the necessary monitoring and reasoning capabilities for teamwork such as building and maintaining a team mental model that optimizes the teamwork.

Which knowledge needs to be shared in a team in order to achieve good team performance depends on context. What knowledge should be shared by which team members depends, e.g., on a team's values (robustness, information security, efficiency), and structure (sub-teams, hierarchy). For example, sharing knowledge about team members may have a larger effect on team performance when all team members have unique capabilities, than when they all have the same capabilities.

To use the idea of shared mental models for developing effective teams and team agents while accounting for the context-sensitivity of sharedness, we introduce the notion of context-sensitive sharedness criteria. Existing literature on team mental models states that sharedness of mental models can involve multiple topics. Cannon-Bowers et al. [1], for example, distinguish equipment-related, task-related, team members-related, and team interaction-related knowledge. There is no framework, however, for expressing to what extent a certain type of knowledge should be shared among which members of a team.

In the remainder of this extended abstract, we will distinguish three elements of sharedness criteria: *how much*, *what*, and *among whom* knowledge in a team should be shared. We will provide a non-exhaustive list of options for each of these three elements, and discuss under what kind of contexts and for what sorts of teams these criteria are relevant. By introducing sharedness criteria we aim to contribute to understanding of the dynamics of teamwork, prediction of team performance, evaluation of teamwork, and the development of agents that are to act in a team.

## 2. SHAREDNESS CRITERIA

### 2.1 How much knowledge to share?

To choose the extent $\theta$ to which knowledge in a team needs to be shared several considerations should be taken into account. Multiple studies in different context have found a positive relationship between sharedness of team mental models and team performance [6,7]. This would call for a high $\theta$. However, literature also suggests that too much similarity among group members may result in groupthink, the phenomenon that group members do not critically evaluate of alternative ideas or viewpoints in order to minimize conflict [1]. Moreover, current research on team mental models suggests that the notion 'more sharedness results in higher team performance' is too simplistic, and that team role structure and team task should also be considered [8].

### 2.2 What knowledge to share?

*Task versus team knowledge*: In the literature on teamwork, team members are considered to have multiple mental models. A distinction is made between task-focused mental models, regarding topics such as work goals and performance requirements, and team-focused mental models, including the interpersonal interaction requirements and skills of other team members [8]. This distinction yields two possible options for the type of knowledge in sharedness criteria: sharedness of task

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knowledge and sharedness of team knowledge. In several studies similarity of task knowledge was found to have stronger effects on team performance than similarity of team knowledge [7].

*Intentions vs de facto knowledge*: Literature on teamwork has focused mostly on sharedness of what we call here 'de facto' knowledge [8]. De facto knowledge involves knowledge about general properties and the current state of the environment and team members, and can be contrasted to knowledge about intentions, which refers to knowledge about desired states and what activities team members intent to do in the (near) future. To make sure information about intentions is shared, team members are obliged to "inform before doing", i.e., to communicate its intention to do something before actually doing it.

*Accuracy wrt expert knowledge*: The options discussed so far in this section regard certain categories of knowledge that need to be shared. An alternative option is to look at the accuracy of the team members' mental models. In the literature, mental model accuracy has mostly been measured against the judgment of multiple subject matter experts, after establishing reasonable inter rater reliability [4]. Instead of considering in-team sharedness of a certain type of knowledge, expert opinions can be used as a criterion for what knowledge should be shared in a team, and whether the knowledge in the team is of sufficient quality.

## 2.3 With whom to share knowledge?

*Key members*: In most empirical studies on team mental models, individual mental models are compared with each other to determine a similarity or sharedness value for the team. In that, mental models of different team members are usually weighted equally [3]. In teams with distinct roles, however, different team members may require different amounts of mental model sharedness for good team performance. For example, team members with a management role may need to have high sharedness values with each of the team members, whereas sharedness among the other team members is not a requirement for good team performance. An example of where this criterion is applied is a team operating in a hostile situation in which team members may be captured and interrogated, e.g. in terrorist organizations.

*Sub-teams*: Another situation in which different sharedness criteria may be applied to different members of the team is when a team is divided in sub-teams that are each responsible for part of the team's tasks. Provided that there are none or little dependencies among the tasks of the sub-teams, there is no need for high sharedness levels among sub-teams. If each sub-team has a leader that is responsible for the coordination of activities between sub-teams, 'normal' members of a sub-team do not need to have high sharedness levels with members of other sub-teams.

*Spread of knowledge*: Some sharedness criteria only help to predict team performance when they are applied to a static team, but it is also possible to create sharedness criteria that take changes in the team into account. An example of such a criterion is that every piece of critical information should be shared by at least *n* team members. When this criterion is satisfied, no information is lost when one of the team members leaves the team. This is relevant for circumstances in which recovery of knowledge is important as team members might be lost, but in which no actor has to know everything. For example, job changes happen frequently in all bigger organizations, and new team members get the information they need by talking to a number of other team members.

Combinations of criteria are of course possible. For example, all (100%) of the members should share intentions to at least 90%, only the two members with leading roles need to know about the capabilities of the other members, only the two leading team members should share the task model to 100%, the other team members can suffice with the overall goal, and their own tasks in the team.

# 3. DISCUSSION

The sharedness criteria can serve as requirements for the engineering of artificial team members, using it to design agents that can achieve better sharedness with their team members.

Furthermore, the sharedness criteria can serve as the evaluation measures for teams (either hybrid, purely human, or purely artificial). This evaluation can be done in training phases, but also after the deployment of a team, as part of the debriefing of the team. The advantage of using a model of sharedness over only measuring team performance is that causes of good or bad team performance can be identified (as far as pertaining to sharedness) by applying the model to analyze to what extent necessary sharedness is obtained.

We see the process of developing sharedness criteria for teams as a task for domain experts. Yet, it could be helpful to develop guidelines on how these experts should come to a set of sharedness criteria.

We see vast opportunities for collaboration and cross-fertilization between the social sciences and computer sciences with regard to team mental model research. We believe that the more shared the models in both fields become, the more joint progress can be made.

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