# A Method of Team Communication Analysis Based on a Team Cognition Model and Task Analysis

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**Abstract.** Effective communication is believed to be essential for positive teamwork, and thus team communication has received much attention from human factor researchers for analyzing team cooperation. This study aims to propose a method of team communication analysis that can contribute to investigating changes of team cooperation in terms of team cognition possessed by a team member. In the beginning, a communication classification matrix that consists of the category of intentions derived from a team cognition model based on mutual belief and that of contents derived from a task analysis is developed. Subsequently, the matrix is applied to team communication data. Finally reasons behind changes of team cooperation are discussed according to the analyses. The results imply that the combination of both categories can contribute to understanding changes of team working in terms of team cognition.

**Keywords:** Communication analysis, teamwork, a cognition model in team, and task analysis.

## 1 Introduction

Effective communication is believed to be essential for positive teamwork, and thus team communication (verbal communications, gestures, etc.) has received much attention from human factor researchers for analyzing teamwork; a serious problem of traditional methods, including the number of utterances of each team member, the duration of communication, and social network analysis, is probably that the results from these methods can show superficial descriptions of team behaviors but cannot explain reasons behind the differences of team working in terms of cognition possessed by a team member, because the traditional categories are not based on any team cognition model possessed by a team member. To better understand and analyze team working in terms of team communication, it will be necessary to create communication categories derived from a team cognition model possessed by a team member. This study aims to propose a method of team communication analysis that can contribute to investigating changes of team behaviors and team cognition behind the changes of team cooperation. The next section explains a team experiment, which was conducted our previous study [1], that provides the team communication data to which that the proposed approach is applied to, because the explanation of a team task is necessary to explain our proposed method.

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## 2 Experiment

**Task and Participants.** An air traffic control simulator was used for a task. Participants were asked to route arriving and departing aircraft both safely and accurately. During the session, the aircraft randomly appeared on the display. Each two-person team comprised a "Selector," who had only a mouse, and a "Commander," who had only a keyboard. The standard operating procedures of the task were as follows: the Selector selected the aircraft to which they would give a command with the mouse. Then, the Commander would enter a command for the selected aircraft using the keyboard. Because the number of aircraft increased in the second and third sets, team members had to reallocate team resources in the sets; otherwise, they would fail to manage the aircraft. Twenty-two graduate/postgraduate students (11 teams) participated.

**Instructions for Reflection, Procedures, and Team Performance Indices.** Two-types of metacognitive instructions on cooperation were designed and applied. One was "Team-oriented instruction" whose instruction was "How is this task being operated by your team?" (6 teams), and the other one was "Self-oriented instruction" whose instruction was "How do you cooperate in this task?" The participants were asked to reflect on these instructions (5 teams). The participants practiced the operation until they could smoothly land and transfer an aircraft. The total trial duration was 15 min for all participants. The metacognitive instruction was presented every 7.5 minutes and the participants read it and wrote down their own cognitive status and beliefs twice in each set. When the instruction was presented, the display turned blank and the simulation was suspended. The participants sat face-to-face, and communicated freely with each other, except when they were responding to the instructions. Some teams could not participate in the third set because of their schedules. Two types of game score were used as team performance indices: safety violation time and number of aircraft successfully processed. Safety violation time was the duration in seconds of when the distance between two different aircraft was less than 1,000 feet vertically and 3 miles laterally. The number of aircraft successfully processed was calculated by subtracting the number of failed landings or improper exits from the airspace from the number of successful landings or successful transfers to other airspaces at the handoff points.

## 3 Development of Categories

In order to develop utterance categories that can represent the meanings of each utterance by a minimum number of categories, a communication classification matrix is created by combining the category of intentions derived from a team cognition model based on mutual belief [2] with the category of contents derived from a hierarchical task analysis. The category of intentions can examine the changes of intentions behind changes in team behaviors, while the category of contents can help identify subtasks where the changes in team behaviors occur.

**The Category of Intentions.** A team cognition model based on mutual belief describes team cognition as a set of three layers of mental processes and constructs, interaction between the different layers, and metacognition for cooperation. In a dyadic case (Agent A and B), the model is composed of the following three layers:

- The first layer (Ma/Mb) = an individual cognition that contains various mental processes and constructs except beliefs.
- The second layer (Ma'/Mb') = a belief in the partner's cognition.
- The third layer (Ma''/Mb'') = a belief in the partner's belief.

There are two types of interactions between different layers; intra- and inter-personal. Intra-personal interactions are manipulations of one's own mental components between different layers and are assumed to be involved in updating one's own cognition and in inferring a partner's cognitive status. Inter-personal interactions are communication and the direct or indirect observation of the behavior of others and can update the partner's layers. Metacognition for cooperation means monitoring and assessing the current status of each of one's own three layers in terms of, for example, sufficiency, conviction, and consistency. The metacognition for cooperation has been assumed as the beginning of team cognitive processes. Based on the metacognition, a team member could be motivated to increase sufficiency and conviction, or to maintain consistency among the status of each layer. In this study, these motivations are defined as communication intentions. The category of intentions is derived from the team cognition model (Table 1).

**Table 1.** The Category of Intentions

| Intentions | Definition |
|---|---|
| Inform | To add new information to the partner's cognition/belief.<br>To verify the partner's cognition. |
| Correct Cognition | To correct mistakes in the partner's cognition.<br>To make the partner reflect about his/her cognition. |
| Correct Belief | To correct mistakes of the partner's belief.<br>To make the partner reflect about his/her belief. |
| Check Cognition | To query others to check/complement his/her own cognition.<br>To signal defects in his/her own cognition. |
| Check Belief | To query others to check/complement his/her belief on his/her partner's cognition (to elicit his/her partner's cognition). |
| Acknowledge | To agree with his/her partner. (Reply to "Inform.")<br>To acknowledge "Inform". (Reply to "Inform.") |
| Interjection | To withhold his or her judgment. (Reply to "Inform.") |

**The Category of Contents.** The category of contents is derived from hierarchical task analyses. The procedure of the task used in this study was as follows. In the beginning, participants need to understand the traffic situation such as positions and flight paths of aircraft. In addition, they need to check instructions given to aircraft.

Subsequently, participants need to give aircraft adequate instructions, including flight level control and flight direction, to route arriving and departing aircraft. The category is given in Table 2.

**Table 2.** The Category of Contents

| Contents | Definition |
|---|---|
| Landing clearance | Decisions about clearance for landing aircraft and selecting appropriate runways. |
| Departing clearance | Decisions about clearance for departing aircraft. |
| Plan | Plans and instructions given to aircraft (flight direction and level). |
| Aircraft status | The status of instructions that aircraft have been given. Discrimination between arriving and departing aircraft. |
| Traffic situation | Positions of aircraft, the distances between aircraft, and appearance of new aircraft. |

**The Communication Classification Matrix.** Based on both the category of intentions and the category of contents, a communication classification matrix is constructed (Table 3). The matrix is used to classify team communications for analyses of team cooperation.

**Table 3.** The Communication Classification Matrix

| Intentions | Contents | Commander | Selector |
|---|---|---|---|
| Inform | Landing clearance | | |
| | Departing clearance | | |
| … | … | | |
| Interjection | Traffic situation | | |

## 4 Results and Discussion

Table 4 shows the number of aircrafts successfully processed and safety violation time. The average number by the team-oriented instruction team improved in the second and third sets, while that of the self-oriented team remained the same. The average safety violation time of the team-oriented instruction team remained the same in the second and third sets, while that of the self-oriented instruction team increased in the second set. These results imply that team members in the team-oriented instruction changed their team behaviors to improve their team processes. We applied the proposed method to the communication data to investigate a part of reasons behind the changes. Although it is possible to compare the two conditions according the communication analyses by the method, this paper focuses on the transition of the measured "Check belief" ratios due to limitations of space (Table 5). The results imply that the "Check belief" ratio for "Plan" under the team-oriented instruction increased in the second and third sets. These results imply that some of the team

members under team-oriented instruction became to give their partner initiative about making plans and actively check their partner's thoughts about plans to make a quick team decision in situation where team members have to deal with multiple tasks in parallel.

**Table 4.** Game Scores

| | Team-oriented instruction | | | Self-oriented instruction | | |
|---|---|---|---|---|---|---|
| | 1st set | 2nd set | 3rd set | 1st set | 2nd set | 3rd set |
| Number of Aircrafts Successfully Processed | 3.67 | 7.50 | 8.33 | 5.80 | 6.00 | 5.00 |
| Safety Violation Time | 264.00 | 222.00 | 204.00 | 226.60 | 378.80 | 152.25 |

**Table 5.** "Check belief" Ratios

| | Team-oriented instruction | | | Self-oriented instruction | | |
|---|---|---|---|---|---|---|
| | 1st set | 2nd set | 3rd set | 1st set | 2nd set | 3rd set |
| Landing clearance | 0.00 | 0.06 | 0.00 | 0.12 | 0.16 | 0.08 |
| Departing clearance | 0.62 | 0.73 | 2.02 | 1.26 | 1.04 | 1.23 |
| Plan | 1.75 | 3.16 | 2.69 | 1.06 | 0.78 | 0.60 |
| Aircraft status | 0.24 | 0.54 | 0.84 | 0.00 | 0.12 | 0.28 |
| Traffic situation | 0.08 | 0.20 | 0.32 | 0.08 | 0.00 | 0.08 |

## 5 Conclusion

In order to develop a method for investigating reasons behind changes of team cooperation in terms of team cognition, this study proposed a team communication matrix that consists of two utterance classification categories; one is the category of intentions derived from a team cognition model based on mutual belief, and the other is the that of contents derived from a task analysis. We applied the method to the communication data collected in our previous study. The analysis implied that the combination of both categories can enable systematic and detailed descriptions of characteristics of team cooperation in terms of team cognition possessed by a team member.

## References

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