Analysis of Team Communication and Collaboration in En-Route Air Traffic Control

Kazuo Furuta[1], Yusuke Soraji[1], Taro Kanno[1], Hisae Aoyama[2], Daisuke Karikawa[3], and Makoto Takahashi[3]

[1] Department of Systems Innovation, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
{furuta,soyraji,kanno}@cse.sys.t.u-tokyo.ac.jp
[2] Air Traffic Management Department, Electronic Navigation Research Institute,
7-42-23 Jindaiji-higashi-machi, Chofu 182-0012, Japan
aoyama@enri.go.jp
[3] Department of Management Science and Technology, Tohoku University,
6-6-11 Aoba, Aramaki, Aoba, Sendai 980-8579, Japan
{daisuke.karikawa,makoto.takahashi}@most.tohoku.ac.jp

Abstract. Ethnographic field observation was carried out at the Tokyo Air Traffic Control Center to obtain video, radio communication, verbal conversation, and journal records. Having analyzed these data based on the cognitive model of a radar controller of our previous work and a notion of Team Situation Awareness (TSA), a cognitive model of an ATC team has been established. It was revealed that instantiation of TSA heavily owes to verbal communication but that role assignment among team members is implicitly and smoothly determined once TSA has been established. Team cognitive process of ATC controllers is therefore well described by TSA development and Naturalistic Decision-Making (NDM).

Keywords: Aviation safety, air traffic control, human factors, team cognitive model, task analysis.

1 Introduction

Due to increasing air traffic demands, it is expected that workload on Air Traffic Control (ATC) tasks will also increase. Prevention of human errors in ATC is therefore a key issue for keeping a high level of air traffic safety and reliability. Cognitive aspects of ATC have not yet been studied in depth, e.g., no comprehensive and concrete measures of ATC performance have been proposed. With this background, our research project aims at constructing a cognitive model of ATC and proposing a quantitative measure of ATC performance finally to establish the technological basis of ATC human factors.

This paper focuses on team collaboration among ATC team in en-route air traffic control, which is for controlling air traffic in the cruising phase of aviation. For en-route air traffic control, air routes are divided into several segments of controlling areas

M.J. Smith and G. Salvendy (Eds.): Human Interface, Part II, HCII 2009, LNCS 5618, pp. 758–765, 2009.

called sectors. An ATC team of two controllers takes charge of each sector: a radar and coordinator controller. Another controller will join the team for acknowledging flight clearance in a busy sector, but this study considers just an ATC team composed of two members as shown in Fig. 1.

Our previous study showed that cognitive process of a radar controller can be described well with a concept of routine [1]. Since an ATC team performs ATC tasks in collaboration, modeling individual cognitive processes is insufficient to understand ATC tasks. This study is therefore aims at constructing a cognitive model of team collaboration process of controllers based on ethnographic field observation of en-route ATC tasks.

Fig. 1. Work situation of en-route air traffic control

2 Field Observation

We carried out ethnographic field observation to obtain basic data for analyzing ATC tasks. Data was obtained at the Tokyo Air Control Center from May 7th to 11th, 2007, during daytime periods when a certain level of workload was imposed on controllers due to relatively heavy traffic. Two video cameras were used to record activities of controllers and another one to record the radar screen of an auxiliary controlling console showing the same radar image of the controllers in charge. An IC voice recorder installed above the radar screen recorded conversation between controllers. In addition, records of radio communication between radar controllers and pilots, positions, ground speeds, altitudes of air traffic, which were shown on the radar screen and stored in a computer of the control center, were obtained.

The target sector of observation is called “Kanto-north” (T03), which covers the northern area of Tokyo. A lot of air traffic overpasses this sector while departing from and arriving at two huge international airports, Haneda and Narita, as well as smaller

airports and air bases. For this reason, this sector is suited to observe various types of en-route ATC tasks.

3 Data Analysis and Result

Obtained records of controllers' conversation and actions were transcribed, segmented according to the units of basic ATC instruction, and then analyzed by goal-means task analysis [2] or distributed cognitive analysis [3]. The aim of the analysis is to understand cognitive process of en-route air traffic controllers, in particular, collaboration between a radar and coordinator controller, and coordination task with neighboring sectors by a coordinator.

Since the cognitive process of a radar controller can be described with a routine, the process that a controller team formed shared recognition of a common routine was a point of team collaboration. We carried out this analysis relying on a notion of Team Situation Awareness (TSA) that is defined based on mutual beliefs [4].

The example cases described below show how an ATC team develops TSA in a specific ATC situation through verbal or non-verbal communication. These cases are based on the situation actually occurred in about 15 minutes after 14:45. May 7th, 2007 at the Tokyo Air Control Center.

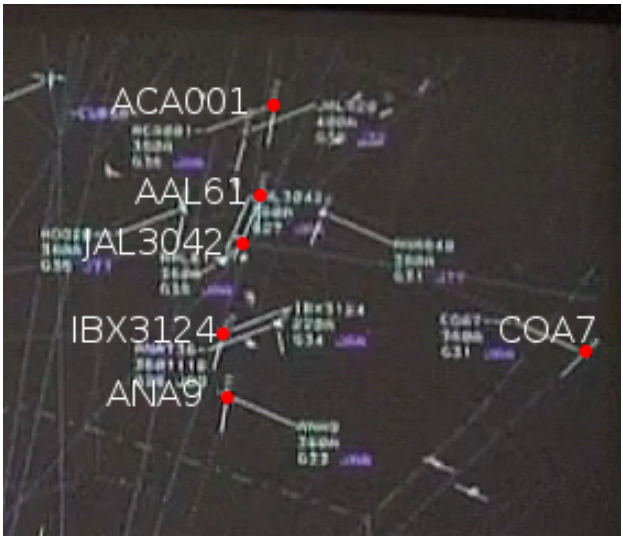

Fig. 2. Situation of air traffic in Case 1

3.1 Case 1

In the first case six aircrafts bound for the Narita airport were about to enter Sector T03 from the north almost at the same time (Fig 2). The controllers have to hand off

traffic approaching the Narita approach at FL150 with a separation of more than 10NM in trail. Both the radar and the coordinator controller recognized the situation of the six aircrafts independently from the flight plans and display on the radar screen.

The controllers communicated each other to share situation awareness and the spacing strategy to be used. This process is shown in the protocol of Table 1. They discussed verbally in what order the descending aircrafts should be lined up in trail. From the contents of communication and the positions and speeds displayed on the radar screen, they shared understanding of the situation.

In this early stage, since the aircrafts were still flying within the neighboring sector, T02, the controllers of Sector T03 were not allowed to control them directly. They wanted, however, to control the aircrafts before they would enter Sector T03 to achieve smooth spacing. The coordinator proposed to request early hand-off from Sector T02 and its proper timing. In this process the ATC team decided the arriving order of the six aircrafts and requesting early hand-off of four aircrafts among them from Sector T02. At the end of the process the coordinator started to request early hand-off of JAL3042 to the coordinator of Sector T02.

Table 1. Team communication in Case 1 (14:45-14:47)

Speaker	Contents of communication
Radar	Consideration on the order of arrival watching the radar screen
Coordinator	Proposal of early hand-off from Sector T02
Radar	Presenting intention to keep vertical separation with an aircraft bound for Haneda
Radar	Consideration on the order of arrival of the aircrafts coming from northeast
Coordinator	Presenting opinion on the order of arrival
Radar	Agreement to the coordinator's opinion, but presenting concern about change in speeds
Coordinator	Speed monitoring and proposal of 15NM separation in trail
Coordinator	Confirmation of the 4th and 5th aircraft to arrive
Coordinator	Rearrangement of flight data strips according to the agreed order of arrival
Radar	Statement that they should already start spacing if 15NM separation is to be adopted
Coordinator	Suggestion of early hand-off from Sector T02
Radar	Request coordination for early hand-off of three aircrafts
Radar	Presenting intention on control strategy
Coordinator	Presenting decision to request hand-off of JAL3042

3.2 Case 2

Having finished coordination of the early hand-off with Sector T02, the coordinator performed his own part of ATC tasks by sharing situation awareness with the radar controller. Here the coordinator drew attention of the radar controller to the traffic that might interfere the aircrafts under control. In addition, they discussed the means of control instruction. The radar controller informed of his own thinking process to

the coordinator before issuing control instructions to the pilots. This action contributed to share understanding of situation between the controllers.

Since wind would affect flight paths of the aircrafts in this situation, the controllers had to adjust prediction of the future watching the situation. Sharing the strategy and the means to be used is very important for smoothly achieving such adjustment, because delay in issuing control instructions will cause subjective difficulties of ATC tasks such as workload increase.

In this process the coordinator proposed coordination with Sector T02 on heading and altitude of the aircrafts under control, and the communication was the process to form consensus on the overall spacing strategy. Thereafter the radar controller issued control instructions to the pilots following the agreed strategy, and the coordinator conducted coordination with Sector T02. Having finished individual tasks separately, they achieved smooth spacing of the target aircrafts. From a viewpoint of distributed cognition, sharing of situation awareness and spacing strategy as well as proper division of tasks among team members led to successful achievement of ATC tasks.

Table 2. Team communication in Case 2 (14:48-14:51)

Speaker	Contents of communication
Radar	[Having heard coordination of hand-off of aircrafts flying in southern area of JAL3042] Acknowledgement
Coordinator	Drawing attention to the aircrafts to be kept in mind
Radar	Identification of an aircraft with no relation to the targets
Coordinator	Concern about change in speed
Radar	Consideration on the mean of separation
Coordinator	Proposal of heading request to Sector T02
Radar	Disagreement of the proposal explaining relation with another aircraft that might interfere
Coordinator	Agreement
Coordinator	Proposal to change heading of ANA736
Radar	Agreement of directing ANA736 to AY (Kumagaya)
Coordinator	Proposal of destination and tentative altitude
Radar	Agreement
Coordinator	Confirmation of tentative altitude
Radar	Agreement

3.3 Case 3

Having been allowed to instruct all of the aircrafts to be spaced, the ATC team communicated to follow the changing situation so that they can maintain the common strategy of spacing. The communication shown in Fig. 3 represents this process. The radar controller requested the coordinator to carry out coordination with Sector T02 on the heading of an aircraft there to follow the strategy they adopted. The coordinator responded by starting the coordination immediately. Some changes in the means adopted for separation were necessary, but they responded properly by monitoring the situation and by communicating frequently.

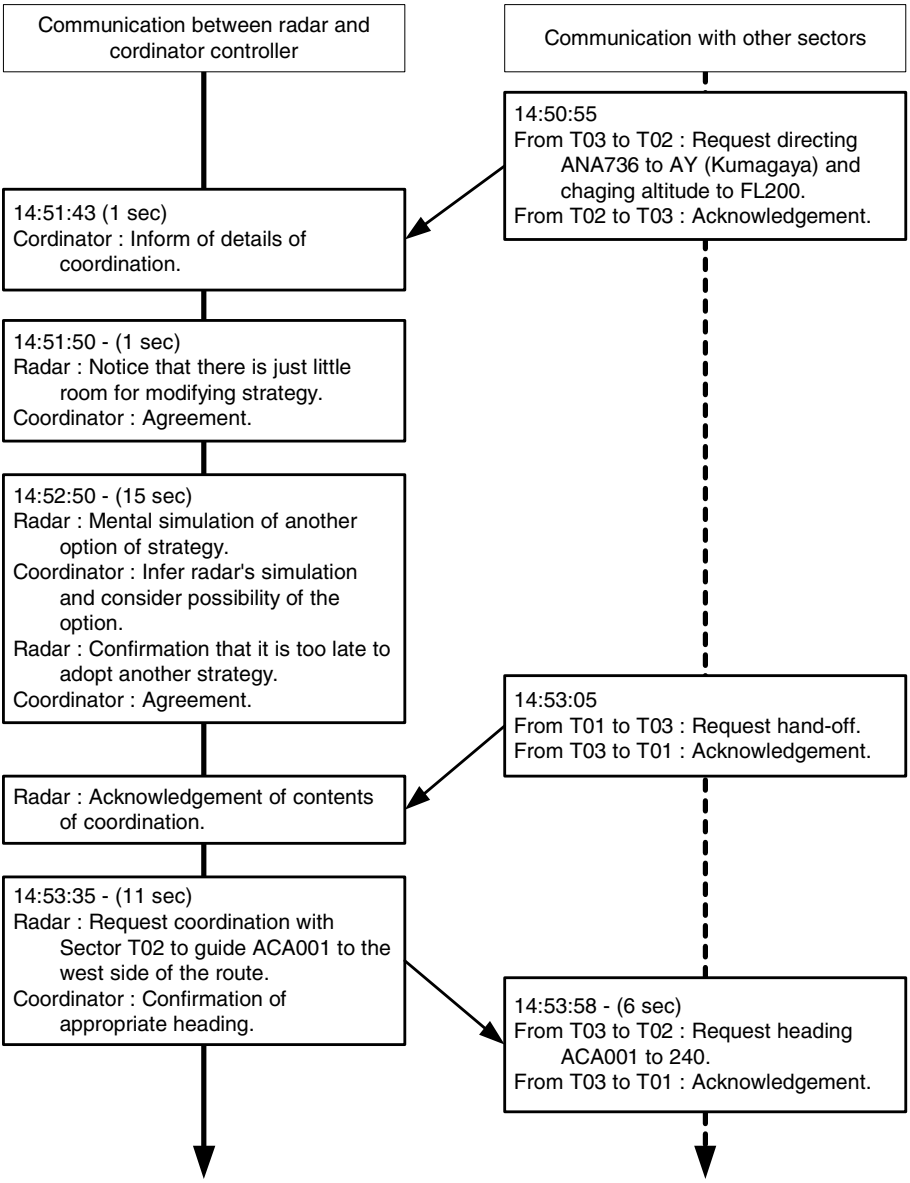

Fig. 3. Sequence of communication and coordination in Case 3 (14:50-14:54)

4 Discussion

We revealed the role of a coordinator controller and features of team work in en-route ATC from data obtained by ethnographic field observation.

It is the most important task for smooth collaboration among an ATC team to establish TSA on air traffic in the target sector. If it is possible to obtain TSA from information in the environment that is observable by the both team members independently, such as the radar screen and flight data strips, verbal communication is unnecessary for obtaining TSA. Such a case, however, applies just to relatively simple situations. In more complicated situations such as shown in the case study, more active communication is used to develop TSA where one will explicitly state his/her own awareness on the situation.

Once the team has established TSA, they usually decide task assignment implicitly and then carry on to task execution. A radar and coordinator controller distribute tasks between them in this phase, and it seems that they have agreed on task allocation beforehand in case of complicated situation or heavy traffic. It suggests that the Naturalistic Decision-Making (NDM) [5] model can apply to the distributed cognitive process in team collaboration of the controllers. In NDM, recognition of situation directly leads to decision-making for the recognized situation without assessing and comparing many options for the decision. A routine, which is the cognitive model of a radar controller, plays an important role also in the NDM by an ATC team. It is because both a radar and coordinator controller, who are trained and qualified in common, are well aware of the same routines.

In summary, a model of team collaboration for en-route ATC can be well described that an ATC team develops TSA based on routines shared in common and then they makes a decision following the NDM model based on the obtained TSA.

5 Conclusion

We analyzed the data obtained by field observation at the Tokyo Air Control Center based on the cognitive model of a radar controller and a notion of TSA. Consequently, it has been shown that an ATC team tries to shape and share TSA actively by verbal communication and that they decide task assignment between team members smoothly and implicitly once they have established TSA. From these findings, team cognitive process of controllers can be modeled as TSA development and NDM.

Acknowledgements. The authors wish to express their thanks to the Japan Railway Construction, Transport, and Technology Agency who supported this work under the Program for Promoting Fundamental Transport Technology Research.

References

1. Inoue, S., Aoyama, H., Kageyama, K., Furuta, K.: Task Analysis for Safety Assessment in En-Route Air Traffic Control. In: Proc. 13th Int. Symp. on Aviation Psychology, Oklahoma, USA, pp. 253–258 (2005)
2. Hollnagel, E.: Human Reliability Analysis, Context and Control, pp. 220–228. Academic Press, London (1993)

3. Artman, H., Garbis, C.: Situation Awareness as Distributed Cognition. In: Proc. Euro. Conf. Cognitive Ergonomics, pp. 151–156 (1998)
4. Shu, Y., Furuta, K.: An inference method of team situation awareness based on mutual awareness. Int. J. Cognition, Technology, and Work 7(4), 272–287 (2005)
5. Klein, G.: The Recognition-Primed Decision Model: Looking Back, Looking Forward. In: Zsambok, C.E., Klein, G. (eds.) Naturalistic Decision Making, pp. 285–292. Lawrence Erlbaum, Mahwah (1997)