

Cooperation, interactions and socio-technical reliability: the case of Air-Traffic Control. Comparing French and Irish settings

Laurence Rognin

*Interaction Design centre
University of Limerick, Limerick, Ireland
laurence.rognin@ul.ie
<http://www.ul.ie/~idc/about/people/laurence/laurence.html>*

Pascal Salembier

*ARAMIHS-IRIT UPS, 118 route de Narbonne
31062, Toulouse cedex, France
salembier@isp.fr
www.irit.fr/ACTIVITES/GRIC*

Moustapha Zouinar

*ARAMIHS-IRIT UPS, 118 route de Narbonne
31062, Toulouse cedex, France
zouinar@cena.dgac.fr
www.irit.fr/ACTIVITES/GRIC*

Keywords

Cooperative Work, Communication, Air-Traffic Control, Reliability, Mutual awareness, Mutual Monitoring.

INTRODUCTION

Cooperative activities in complex systems have been the focus of various studies along the past decade, interested either in people's use of the systems, people's interactions and modes of cooperation and lately relation between human activities and so-called global reliability.

Recently, various ethnographic studies highlighted the importance of field studies and the impact of such studies upon design (Filippi and Theureau, 1995; Heath et al., 1995).

The domain of Air-Traffic control is one of the most and widely analysed in this context (see for example Bressolle et al., 1995; Hughes et al., 1992, salembier, 1994). Indeed it combines the features of safety-criticality, cooperative environment and high technologies. In this domain, people (air-traffic controllers) are performing cooperative activities while using various computer systems and "human-machine" interfaces.

Despite the presence of local failures (both human and technical), the system is globally reliable, as very few accident occurred these past years.

In the present paper, we aim to describe cooperative processes observed in air traffic control rooms, and highlight how they indeed contribute to the global reliability of ATC systems. Field studies of air-traffic control have been performed in two different countries (France and Ireland). The comparison of the observed and collected data leads us to underline the

emergence and use of similar processes, in spite of organisational and technical differences.

This paper is composed of three parts. First, the working situations are presented, in describing both the similarities and the differences between the work settings. In the second part, underlying processes such as mutual awareness, mutual monitoring and communication are illustrated with examples issued from the field studies. In the last part, we discuss the presence of similar processes, despite the local organisational and technical specificities and conclude with the adaptive nature of human contribution in complex work settings.

AIR-TRAFFIC CONTROL IN EUROPE

Field studies have been performed in air-traffic control centres both in France and Ireland. The data collection consisted first in task description (through visits and interviews with the management). Later, video-recordings of the actual activities were performed during peak hours. In this section, we describe successively the basic activity of air-traffic control, the similarities and the differences between the two work settings.

The activity of Air-Traffic Control

The activity of controlling the Air-Traffic differs according to the geographic area concerned as well as the location of planes in the air space. Three main sectors of control are usually identified, the en-route, the approach and the tower. The last one deals with the landing and take-off, as well as the parking of planes, while the second refers to the movements of planes (descend or climb) between high levels (en-route) and (called en-route) and the ground level.

In the present studies, we focused on the en-route activities, which will be described more precisely in the final paper.

The Irish case

Control Room
 Controller workplace and supports (one radar, stereo headset)
 Task distribution
 En-route control in Shannon
 Conventions in Strip handling

The French case

Control Room
 Controller workplace and supports (two radar screens)
 Task distribution
 En-route control in Athis
 Conventions in strip handling

Different organisations

The focus of this paper is to highlight how similar activities are performed in different locations while using specific work settings. Indeed, it is interesting and not surprising to notice that despite an overall similarity and a feeling of identical environment, the two control centres present different properties.

In order to compare the two work settings, we decided to take into account various dimensions of the activities, which are the organisation of work (task distribution and contents), the agents' location, the technical and human resources available to each controller.

Similarities between France and Ireland at these various aspects will be described. These are for example the colocation of agents at similar positions, the existence of similar resources (radar, strips, verbal instructions). The purpose of this paper is not to present an exhaustive description of the two settings, but rather to underline how different controllers in different work settings perform similar activities, implementing similar mechanisms in order to achieve the same goal (ensure the process and the safety of ATC).

In this paper we restrict the description of the situations to aspects we identified as relevant regarding our research objectives.

General view of the work setting.

If we consider a specific position of control, the main actors involved in en-route control are similar in both location, and are: one executive controller, one radar controller, pilots in radio contact, controllers in charge of other sectors and a coordinator (figure 1).

In both location the two controllers are seated side by side, and thus have the opportunity to monitor each other actions, to use complementary modality of communication (verbal / gestual, visual / auditive). The media of communication are also similar (telephone between controllers, radio between controllers and pilots).

In both location the controllers use similar artefacts, which are radar screens, flight strips and strip progress board.

Yet, as we are now going to the quantity, the position and the handling of the artefacts differ in each location. Let us describe each of them in the following paragraph.

Specificity

- radar screen: 2 in France, 1 in Ireland (impact of the shared resource on the mutual awareness: executive controller is perceived when he watches the radar located in front of his colleagues; moreover they tend to use this shared resource as an external support for discussion and problem solving, pointing at it)
- strip handling: different conventions

We will present, for example the specificity of. Besides these points, we want to stress two more differences, one related to the task distribution between radar and planning controller, the different audio networks used in each situation, and the variety in the use of the strips (both in terms of position and progress). The controllers, the other related to the technical choices supporting the distribution of information (Irish use of the stereo feature to distinguish the sound according to the speaker).

Once identified, these similarity and specificity are used to understand how each local team copes with the working situation.

In order to address the problem of system reliability, we direct our analysis on the cooperative dimension of work.

MUTUAL AWARENESS, MUTUAL MONITORING & COMMUNICATION IN COMPLEX COOPERATIVE WORK SETTINGS

As shown by several empirical studies of complex cooperative work settings performed within different domains of research (ethnomethodology, anthropology, cognitive ergonomics, CSCW), the efficient coordination of distributed activities and the reliability of work depend on a set of key processes that are combined dynamically and which lie at the intersection of cognitive and social activities (Martin et al., 1997; Morvan et al. 1996).

Among these various processes, we identified as relevant (i) Communication and the information broadcasting, (ii) Mutual Monitoring, and (iii) Mutual Awareness. This last one can be seen as a subset of the broader notion of Situation Awareness (SA), which received a great deal of attention in recent years particularly in the domain of aviation. Although SA is still a fuzzy concept and not well understood, several different definitions have been proposed. For example, Endsley (1995) defined it as 'the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future'. For Sarter & Woods (1991) SA is the accessibility of a comprehensive and coherent situation representation which is continuously updated in accordance with the

results of recurrent situation assessments. In these definitions, the 'elements' and the 'situation' include member's goals, actions, etc. Thus, SA highlights the importance of "being aware" of other's activities in complex work settings in which cooperation is an important aspect of human activity. Within the present study, this particular and important aspect of SA will be addressed through the notion of mutual awareness.

We now define these processes. Before illustrating them, let us now clarify the processes we have just mentioned and illustrate how they occur in both situation.

Mutual awareness

This notion accounts for the fact that in cooperative work situations, participants track and are often attentive to the activities of their colleagues through overhearing and/or overseeing processes. In other words, they distribute dynamically their attention on the basis of what they have to do at a given time in a given situation and of the relevance of events they perceive contingently or in a planned way. Mutual awareness is principally made possible by the visual or auditory accessibility to other's actions. The public availability of artefacts or tools and of their use also support mutual awareness by allowing participants to understand and make sense of other's actions and to recognise¹ their intentions. More generally, it was observed that people use information provided by artefacts in combination with what they hear or see and with what they know about the situation to make inferences that allow them to attribute intentional states (beliefs, wants, intentions, and so on). So, human cognitive activities and the environment in which they unfold are inseparable. This observation shows also how human cognitive activities in "natural" environment is eminently opportunistic.

Mutual monitoring

Mutual awareness is based on the possibility given to each participant to monitor the activities of the others in the sense that each one can assess the relevance and the consequences of the actions of her/his colleagues. By allowing the detection and repairing of troubles and errors, this process of monitoring plays an important role in the robustness of the global system despite the occurrence of local problems (Rognin et al., 1997).

Communication

Communication allows agents to broadcast information about their activities, their intentional states and also about other events. It helps them directing or drawing the attention of the other participants to relevant events, possible problems and disturbances, etc. Communication may be synchronous or asynchronous, verbal (oral or written) or/and non-verbal (gestures, gaze, etc.). Information conveyed by communicative acts may be mono or pluri-addressed in the sense that it can be

respectively broadcasted to one person or to a set of agents.

The examples issued from the field studies will stress how, despite diversity in organisations and in environmental resources, the controllers use similar processes in order to handle efficiently the working situation. In the next section, we discuss how these operators get round the differences and adapt their behaviours according to the situational constraints.

DISCUSSION

The work settings described in the first section of this paper have been compared in order to examine the impact of the organisation of work and the artefactual environment of each site on the collaborative processes we have mentioned. We took the organisation of work to include individual's tasks, division of labour, physical location in the workspace, procedures and so on. The artefactual environment includes tools (computers, telephones, documents, etc.), external representations embedded in the tools, etc. Within the present study, we also investigate how these organisational and environmental characteristics support the reliability of controller's cognitive activities.

The comparison of the cooperative activities of Air-Traffic control in two different countries enables us to highlight how, despite different working environments, agents perform similar activities, both explicit and implicit.

The results issued from the present comparative field studies do not only confirm the emergence and efficiency of processes such as mutual awareness, implicit information broadcasting, but also provide illustrations of their implementation.

Awareness, which is often mentioned as a central element in cooperative activities (Schmidt, 1994) is here illustrated at two different levels, one we call "focused" awareness, the other usually called "peripheral" (Heath et Luff, 1992). The notion of awareness, although well established in the research community (Dourish, 1997; Bellotti and Rogers, 1997) still requires extensive investigation. In the final paper, we will discuss related concepts, such as mechanisms of acquiring / distributing information, parallel information processing, multimodal processing (audio and visual).

We conclude this paper in stressing how human cooperation plays a main part in socio-technical dependability. Our main argument is that cooperation in shared workspace supports the use of various processes, all contributing to the collective elaboration and updating of mutual awareness, itself the main basis for error-tolerance and prevention.

REFERENCES

- Bressolle, M.C., Pavard, B., & Leroux, M. (1995). The Role of Multimodal Communication in Cooperation and Intention Recognition: The Case of Air Traffic Control. In H. Bunt, R.-J. Beun, & T. Borghuis (Eds.), *Proceedings of the International Conference on Cooperative*

¹ Recognise or at least assume what they might be.

- Multimodal Communication, CMC '95, (pp. 63-78). Eindhoven, Pays-Bas, May 24-26.
- Dourish, P. (1997). Extending Awareness Beyond Synchronous Collaboration. Workshop on Awareness in Collaborative Systems, CHI'97, Atlanta, Georgia. May 1997.
- Endsley M. R., (1995). Toward a theory of situation awareness in dynamic systems. *Human factors*, 37, 1, 65-84.
- Filippi, G. and Theureau, J. (1993) Analysing cooperative work in an Urban Traffic Control Room for the Design of a Coordination Support System. In G. De Michelis, C. Simone and K. Schmidt (eds) *Proceedings of ECSCW93*. Dordrecht: Kluwer. pp. 171-186.
- Heath, C. & Luff, P. (1992). Collaboration and Control. *Crisis Management and Multimedia Technology in London Underground Line Control Rooms*. *Computer Supported Cooperative Work (CSCW)*. An International Journal, 1 (1-2), 69-94.
- Heath, C.C., Luff, P., & Nicholls, G.M. (1995). The Collaborative Production of the Document: Context, Genre and the Borderline in Design. In INRIA (Ed.), *COOP'95 : International Workshop on the Design of Cooperative Systems* (pp. 203-218). January 25-27 ; Antibes-Juan-les Pins, France.
- Hughes, J.A., Randall, D., & Shapiro, D. (1992). Faltering from Ethnography to Design. In J. Turner & R. Kraut (Ed.), *Conference of Computer Supported Cooperative Work* (pp. 115-122). Oct 31 - Nov 4, Toronto, Canada. ACM Press, NY.
- Martin, D., Bowers, J. and Wastell, D. (1997) The Interactional Affordances of Technology: An Ethnography of Human-Computer Interaction in an Ambulance Control Centre. In H. Thimbleby, B. O'Conaill and P. Thomas (eds). *People and Computers XII, Proceedings of HCI '97* (pp. 263-281). Springer-Verlag: London.
- Morvan, E., Rognin, L., & Spérando, J.-C. (1996). Reshaping Task Contents: Operators' Contribution to Systems Reliability. In *Eighth European Conference on Cognitive Ergonomics - ECCE'8*. Granada, Spain, September 10-13.
- Rognin, L., Salembier, P. and Zouinar, M. *Latent Organisational Reliability ALLFN'97, Revisiting the Allocation of Functions Issue* (pp.63-71). Galway, Ireland, October 1-3.
- Salembier, P. (1994). Assistance coopérative aux activités complexes : l'exemple de la régulation du trafic aérien. In B. Pavard (Ed.), *Systèmes coopératifs : de la modélisation à la conception* (pp. 377-407). Toulouse: Editions Octarès.
- Sarter N., Woods, D., (1991). Situation Awareness : a critical but ill-defined phenomenon, *International Journal of aviation psychology*, 1, 1, 45-57.
- Schmidt, K. (1994). Modes and Mechanisms of Interaction in Cooperative Work. *Outline of a Conceptual Framework*. Risø-R-666(EN). Risø National Laboratory, Roskilde, Denmark.