2013

Clarifying Cognitive Complexity and Controller Strategies in Disturbed Inbound Peak ATC Operations

Marian J. Schuver-van Blanken

Mariska I. Roerdink

CLARIFYING COGNITIVE COMPLEXITY AND CONTROLLER STRATEGIES IN DISTURBED INBOUND PEAK ATC OPERATIONS

Marian J. Schuver-van Blanken
Mariska I. Roerdink
Air Traffic Control the Netherlands (LVNL), Human Factor Department
Schiphol airport, Amsterdam, the Netherlands

Air traffic controller (ATCo) expertise is crucial in safely and effectively managing operational disturbances and unpredictable events. The high level of ATCo expertise needed in these situations originates from the cognitive complexity in the ATC task. To cope with cognitive complexity in managing operational disturbances, controllers apply strategies to avoid task performance being compromised. Using the ATCo Cognitive Process and Operational Situation (ACoPOS) model, this paper clarifies the cognitive complexity involved in disturbed inbound peak operation within dense airspace for Schiphol airport at ATC the Netherlands (LVNL). Complexity issues in cognitive processes and operational factors involved are described. Strategies used by expert controllers in response to day to day disturbances in inbound peak operation are described based on results of a focus group. Results indicate the existence of new strategies, supplementary to those found in literature.

Within a wide range of operational situations, air traffic controllers are able to ensure safety whilst keeping the additional goals of efficiency and environment in optimal balance. Especially in managing operational disturbances and unpredictable events, air traffic controller (ATCo) expertise is crucial (Redding, Ryder, Seamster, Purcell & Cannon, 1992; Schuver-van Blanken, Huisman & Roerdink, 2010; SESAR, 2007). However, acquiring the level of expertise needed for handling these situations is one of the main drop-out reasons in air traffic control (ATC) training (Oprins, 2008). The high level of ATCo expertise originates from the cognitive complexity that is inherent in disturbed ATC operation.

Day to day air traffic control is frequently characterized by disturbed operation as a result of dynamic factors in the situation, unpredictable events or complex situations, not necessarily being extreme or exceptional situations. In disturbed operation, traffic handling has to be (temporarily) adjusted or traffic streams have to be (temporarily) rebuild to mitigate the disturbance, while safety is ensured and optimal efficiency is aimed for. The resulting cognitive complexity is determined by both the complex cognitive processes involved as well as the characteristics of the operational situation. To cope with cognitive complexity in disturbed operation, controllers continuously use strategies to adapt their task performance in response to the characteristics and dynamics of the operational situation. Despite the fact that the importance of controller strategies in ATC performance is emphasized in literature, studies that deal with these issues are limited (Fothergill & Neal, 2008; Nunes & Mogford, 2003; Schuver-van Blanken & van Merriënboer, 2012). This paper provides insight in cognitive complexity involved in a situation that is considered prototypical for handling daily disturbances and unpredictable events at ATC the Netherlands (LVNL): inbound peak operation in dense airspace for Schiphol airport. Next, the paper describes the strategies expert controllers apply in response to disturbed inbound peak operation to mitigate cognitive complexity.

The ATCo Cognitive Process & Operational Situation model (ACoPOS)

To analyse and clarify cognitive complexity in ATC, the ATCo Cognitive Process & Operational Situation (ACoPOS) model was developed at ATC the Netherlands (LVNL) (see Figure 1) (Schuver-van Blanken, Huisman & Roerdink, 2010). The ACoPOS model extends the competences of LVNL's ATC performance model (Oprins, Burggraaff & van Weerdenburg, 2006) with elements in the operational ATC situation. This way, cognitive complexity issues can be pinpointed as cognitive processes cannot be seen separately from the context and operational situation in which the tasks are performed. The ACoPOS model was developed based on a literature review in ATC complexity (e.g. Mogford, Guttman, Morrow & Kopardekar, 1995; Hilburn, 2004) as well as the models of Endsley (1995) and Histon and Hansman (2008), together with practical operational experiences. Distinguished in the ACoPOS model are cognitive processes (right-hand side of the model) and the operational situation (left-hand side of the model). By means of the ACoPOS model a picture can be drawn of the ATCo cognitive processes in a certain operational situation and the factors causing cognitive complexity. The model will be explained in the following sections by means of a description of prototypical inbound peak operation in the Amsterdam ACC South sector.

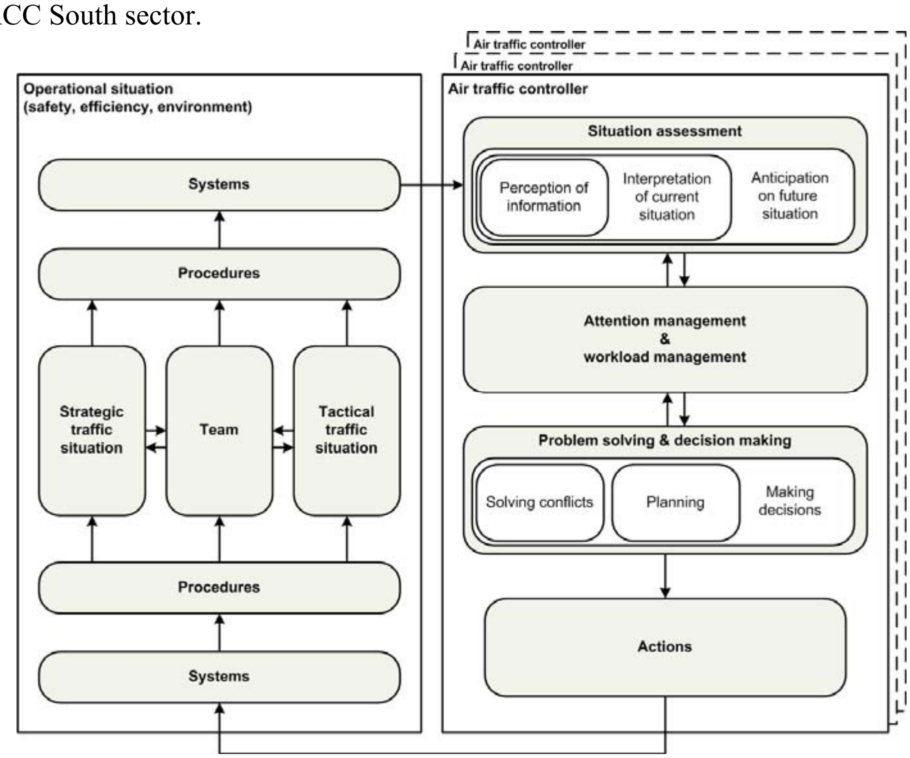

Figure 1, The ATCo Cognitive Process & Operational Situation model (ACoPOS model) (adapted from Schuver-van Blanken, Huisman & Roerdink, 2010)

Operational situation: Inbound peak operation in the Amsterdam ACC South sector

In the current operation at Schiphol Airport, Amsterdam, inbound traffic is delivered at the initial approach fixes (IAFs) by the Amsterdam Area Control Centre (AMS ACC). From the IAFs, tactical vectoring is applied by the Schiphol Approach controllers (SPL APP) to guide traffic to one of the runways. Five area control sectors exist that feed three IAFs. The three IAFs are assigned to a landing runway, with a maximum of two landing runways available at the same time, therefore multiple IAFs merging to a single runway. The South sector is the only sector that feeds traffic to the RIVER IAF. RIVER is different from the other two IAFs in that traffic from this IAF is usually used to balance the traffic amount over both runways, meaning aircraft flying inbound from this sector will often land on different runways and are merged with traffic from the other IAFs.

The ACoPOS model includes factors that define the situation and constitute ATC complexity. The model can be used to provide a structured overview of a prototypical inbound peak situation in the AMS South sector described above, including factors relating to complexity. This overview and these factors are typically determined at ATC the Netherlands by combining human factors analysis with consulting (expert) air traffic controllers. The description below provides an overview of prototypical inbound peak operation in the morning, characterised by many operational disturbances and unpredictable events that have to be handled and part of daily operational practice.

- *Strategic traffic situation:* The strategic traffic situation sets the framework within which traffic has to be handled, such as the traffic volume, the airspace and the runways in use. For inbound peak situation a maximum of 2 landing- and 1 take-off runway is used. Different configurations of runway-use in the inbound peak exist. Further, the South sector has a very limited airspace and traffic volumes in peak operations can be high. Restrictions on declared capacity may apply.
- *Tactical traffic situation:* The tactical traffic situation is characterised by the dynamic nature of the actual situation. Typically, the morning inbound peak is characterised by bunches of aircraft arriving at the same time. Variations in traffic, e.g. crossing and regional traffic or slow climbing traffic (aircraft performance), impact traffic flows. Standard arrival routes are mainly used but interactions with outbound and crossing routes exist. In addition, the wind- and weather-situation impacts traffic handling and can result in traffic delays.
- *Teamwork and interaction:* Air traffic controllers work in various team situations with team members within the ATC centre as well as outside the centre, including pilots and airport actors. Only when prolonged holding situations occur, a separate stack controller is assigned.
- *Procedures:* Procedures describe the formal or standard operating procedures for traffic handling. The morning inbound peak coincides the shift between night and day operation (determined by clocktime) and, dependent on the time of the year, the beginning of the daylight period. Different procedures exist for these variations, for example limitations in runway use during night-time operation or outside daylight conditions.
- *Technical systems:* Air traffic controllers use several systems to perform their tasks and generate information needed. This includes communication systems, planning systems, surveillance systems and decision support tools providing information and alerts to assist the ATCo.

Cognitive complexity issues in inbound peak operation

The characteristics of the operational situation, as described above for a typical inbound peak situation, result in cognitive complexity issues for the ATCo. Sources to identify complexity issues at LVNL are human factors analyses, interviews with controllers and bottlenecks found in acquiring expertise in ATC training at LVNL. The following categories of cognitive processes are distinguished in the ACoPOS model, for which complexity issues can be identified related to the inbound peak situation:

- *Situation assessment:* Situation assessment results in situation awareness, involving: 1) perceiving information, 2) interpreting the actual situation and 3) anticipating how the situation evolves. The complexity of situation assessment is created by, amongst others, frequent changes in the information that is perceived, continuous interpretation required of the solution space available and anticipating on emerging deviations between the actual and planned situation.
- *Attention management & workload management:* ATCos regulate their amount of attention and manage their workload depending on the specific situation. This includes monitoring the situation, directing attention to specific situations and keeping overview over the situation. The need for systematic scanning of the operational situation without being distracted by events and the frequent variations in workload require the ability to focus on specific situations, but also to be able to accelerate and extend the focus to multiple situations.
- *Problem solving & decision making:* ATCos solve problem- or conflict situations, formulate a plan for traffic handling and decide on what course of action to take. In a typical inbound peak, the deconfliction of bunches of traffic creates cognitive complexity. Standard solutions (e.g. speed and altitudes used) are applied, but switching to non-routine traffic handling is often required, increasing cognitive complexity.

- *Actions:* The outcome of the cognitive processes results in actions executed by the ATCo to interact with the operational environment. A busy inbound peak situation is typically characterised by a high RT load.

Air traffic controller strategies in disturbed ATC operation

To ensure safety whilst efficiency and environment are not sacrificed, controllers employ a combination of strategies, adjusted to the characteristics of the situation as well as operational constraints. Strategies reduce the likelihood of overall task performance being compromised (Histon & Hansman, 2008; Loft, Sanderson, Neal & Mooij, 2007; Malakis, Kontogiannis & Kirwan, 2010; Mogford et al., 1995; Nunes & Mogford, 2003). A strategy is defined as a working method or specific class of air traffic control activities that achieves one or more objectives (e.g. safety, orderliness, expeditiousness) within a certain investment of time and effort (Loft et al., 2007). Based on literature, a list of controller strategies has been generated, categorized into the cognitive processes in ACoPOS (see Schuver-van Blanken & van Merriënboer, 2012). However, the question remains which set of strategies are used by controllers in response to disturbed operational situations and whether other strategies exist in addition to those found in literature. Therefore, we started an exploratory study in 2012 focusing on the research question: *Which strategies do radar controllers use in response to disturbed ATC operation?*

To answer this question, retrospective interviews with individual expert controllers have been used, taking a disturbed operational situation they handled themselves as a basis (see Schuver-van Blanken & van Merriënboer, 2012). In addition to this approach, the method of focus groups was used to extract controller strategies, using the ACoPOS model as a basis. The results of a focus group on typical inbound peak operation in the morning as described in the previous paragraph are described below.

Focus group design

The ACoPOS model forms the basis for the structure of the focus group. 11 ACC controllers at LVNL participated, who are responsible for the ACC training of new air traffic controllers, with an average operational ATCo experience of 17 years. The focus group duration was 1,5 hours.

After an introduction on the purpose, a common mindset was created on typical inbound peak operation in the morning at ACC South sector. Four short movies with typical examples of operational traffic handling in an inbound peak in the ACC South sector were used for this. In addition, ACoPOS was used as a basis for a shared understanding of the (disturbing) factors present in typical inbound peak operation as well as to systematically address the cognitive processes involved. Next, expert insights were generated to get indications for strategies in typical inbound peak operation. This was done by probing questions structured around the ACoPOS cognitive processes, available on a large A3 paper as well as in PowerPoint. First, each participant wrote down their individual insights on the probing questions on the A3 paper. Then, each participant brought in their notes in a group discussion, where the insights of the group were collected in PowerPoint. The insights of the group covered both the answers on the probing questions, as well as the explanations on how they act and why.

Results of the focus group

Group results were categorised into answers that were identical or covered the same aspect or goal as well as the related ACoPOS cognitive processes. The categorised results were characterized by the underlying strategies that may apply. To do so, the explanations during the group discussion provided the necessary context for identification and characterization of the underlying strategy. Next, the individual results were analysed in the same way. The strategies that have been emphasized during the group discussion and were present in the individual results of at least 5 experts are presented in Figure 2, structured around the ACoPOS cognitive processes.

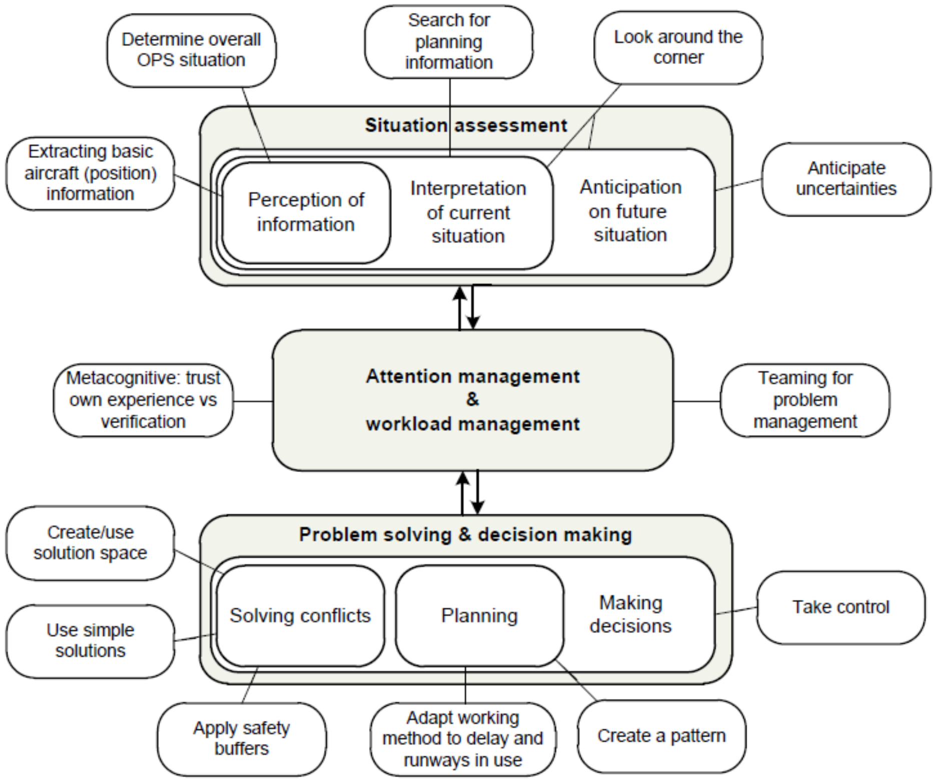

Figure 2, Air traffic controller strategies in inbound peak operation at the ACC South sector

In comparison to the list of strategies from literature (see Schuver-van Blanken & van Merriënboer, 2012), the results from the focus group indicate the presence of the following new strategies:

- *Determine the overall OPS situation*: The overall operational (OPS) situation is determined in a perspective being broader than the traffic situation. This includes weather, wind and visibility circumstances, the runways in use and airspace (un)availability.
- *Search for planning information*: Planning information is actively searched for, regarding (updates of) the expected approach time, the amount of delay or the expected inbound aircraft.
- *Look around the corner*: Controllers look around the corner to determine the traffic situation in the adjacent sector (e.g. traffic density or traffic handling) to be able to pro-actively act on this.
- *Metacognitive*: Results indicate that attention and workload is guided by a metacognitive strategy related to trusting one's own experience in judgment in a specific situation, versus verification of a potential problem situation using tools.
- *Teaming for problem management*: Teamwork with the adjacent sector or the planner controller is important to realize early or partial problem solving or to prevent problems.
- *Create/use solution space*: Controllers create solution space or use available space to solve problem situations. This is also done to prevent problems, to keep other solution possibilities available (e.g. to keep a vector possibility) or to maintain efficiency (e.g. for continuous descend).
- *Create a pattern*: In traffic handling, controllers create a pattern in their traffic handling, e.g. by creating a lateral pattern in vectoring or a structural buildup of the vertical pattern in holding operation. This also helps them to create overview and manage expectancies.

Indications for the strategies 'look around the corner', 'search for planning information', 'create/use solution space and 'create a pattern' were also found in the results of the retrospective interviews that focused on more complex disturbances (see Schuver-van Blanken & van Merriënboer, 2012).

Conclusions and recommendations

Clarifying what constitutes cognitive complexity in operational disturbances and which strategies are underlying ATCo expertise in these situations, enables us both to reduce cognitive complexity in ATC procedures and systems as well as to improve ATC training for acquiring ATCo expertise. By using the ACoPOS model as a framework, the factors influencing and causing cognitive complexity can be made visible. In addition, insights with respect to controller strategies to mitigate cognitive complexity can be systematically revealed. The results of the focus group revealed the strategies used by expert air traffic controllers in response to day to day disturbances in inbound peak operation in the morning in a dense area control airspace. New strategies were found in addition to literature and four of these strategies are in line with the results of the new strategies found in the retrospective interviews focusing on more complex disturbances in peak operation. This might indicate that the new strategies are crucial for mitigating daily disturbances in ATC peak operation. Analysis of additional cases, both by means of retrospective interviews as well as focus groups, is ongoing to determine which strategies are crucial in disturbed ATC operation, both in response to day to day disturbances as well as more complex disturbances.

References

Endsley, M.R. (1995). Toward a theory of situational awareness in dynamic systems. *Human Factors,* 37, 32-46.

Fothergill, S., & Neal, A. (2008). The effect of workload on conflict decision making strategies in air traffic control. In *Proceedings of the Human Factors and Ergonomics Society 52nd Annual Meeting* (pp. 39-43). New York.

Hilburn, B. (2004). *Cognitive complexity in air traffic control – A literature review.* Eurocontrol: EEC.

Histon, J.M. & Hansman, R.J. (2008). *Mitigating complexity in air traffic control: The role of structure-based abstractions.* ICAT-2008-05. Cambridge, MA: MIT.

Loft, S. Sanderson, P., Neal, A & Mooij, M. (2007). Modeling and predicting mental workload in en route air traffic control. *Human Factors, 39* (3), 379-399.

Malakis, S., Kontogiannis, T. & Kirwan, B. (2010). Managing emergencies and abnormal situations in air traffic control (part I): taskwork strategies. *Applied Ergonomics, 41*(4), 620-7

Mogford, R.H., Guttman, J.A., Morrow, S.L., & Kopardekar, P. (1995). *The complexity construct in air traffic control: a review and synthesis of literature*. DOT/FAA/CT-TN95/22. Atlantic City International Airport, NJ: DOT/FAA Technical Centre.

Nunes, A., Mogford, R. H. (2003). Identifying controller strategies that support the ‘picture’. *Proceedings of the 47th Annual Meeting of the Human Factors and Ergonomics Society.* Santa Monica, CA

Oprins E. (2008). *Design of a competence-based assessment system for air traffic control training*. Doctoral dissertation, University of Maastricht.

Oprins, E, Burggraaff, E. & van Weerdenburg, H. (2006). Design of a competence based assessment system for ATC training. *International Journal of Aviation Psychology, 16*(3), 297-320.

Redding. R.E., Ryder, J.M., Seamster,, T.L., Purcell, J.A. & Cannon, J.R. (1991). *Cognitive task analysis of en route air traffic control: Model extension and validation.*ERIC document No. ED 340 848. McLean, VA: Human Technology.

Schuver-van Blanken, M.J., Huisman, H. & Roerdink, M.I. (2010). The ATC cognitive process & operational situation model – a model for analysing cognitive complexity in ATC. *Proceedings of the 29th EAAP Conference,* Budapest, Hungary.

Schuver-van Blanken, M.J. & van Merriënboer, J.J.G. (2012). Air traffic controller strategies in operational disturbances - an exploratory study in radar control. *Proceedings of the 30th EAAP Conference*, Sardinia, Italy.

SESAR (2007). *Human Factors Impact.* SESAR Consortium: SESAR Definition Phase - Task deliverable WP1.7.1./D2.