MANAGING TIME CONSTRAINTS IN AIR TRAFFIC CONTROL-RECOGNITION-PRIMED-DECISION-MAKING IN BUSY AIR TRAFFIC CONTROL SETTINGS

Project work submitted in partial fulfillment of the requirements for the MSc in Human Factors and System Safety

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Nora Gissel

Under supervision of James M. Nyce

Many people have stepped into my life so far; whether for a short or superficial encounter or a deep and lasting friendship or relationship, they all left an imprint on my mind, forming it to what it is now. Each encounter is woven into this thesis. Therefore I thank each person I met for making this thesis possible.

Special thanks go to Professor Sidney Dekker and Professor James M. Nyce for the guidance and inspiration throughout my studies, and to the Air Traffic Controllers in Malmö and Copenhagen ACC who so openly described their experiences.

ABSTRACT

How do Air Traffic Controllers (ATCOs) manage to make safe decisions facing the increasing time constraints created by increasing numbers of aircraft going through their sector? This study uses a qualitative research strategy to investigate what competences ATCOs have to manage this task safely. 8 male controllers from Copenhagen Area Control (ACC) were interviewed. In opposition to the theory that decision-makers try to optimize, i.e. to go for the best solution, Klein's Recognition-Primed-Decision Model is used here instead. Results show that rather than optimize ATCOs have the ability to size up, to assess a situation and recognize it as familiar/typical. ATCOs tend to choose the first workable course of action (satisficing) and therefore are generally able to make fast and safe decisions. Some of the implications this has for the design of technological systems intended to support ATCOs are also discussed.

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Introduction

"Ready for the next victim?" I am standing at the supervisor position in Copenhagen ACC surrounded by the buzzing atmosphere of a busy, but relaxed Air Traffic Control Operations room. Short and precise coordinations sound through the room, relaxed talking and a bit of laughter here and there, and mixed into that the clicking of the plastic Flight-progress-strip holders[1] being sorted and resorted onto the holding tracks, pushed back and forth between positions and thrown into "waste bins" when not needed any longer. This clicking- at present so familiar to the controllers- will have disappeared in about half a year's time when the new strip-less system[2] is going to be introduced.

The supervisor is referring to my next interviewee. At the end of my two days here I will have interviewed a group of 8 male Area Controllers, 6 with over 10 years of experience and 2 with less than 10 years experience.

Why am I doing these Interviews?

Since "One of the outstanding characteristics of today's economies … is an obsession with growth [and] economic and technological growth are seen as essential by virtually all economists and politicians" (Capra, 1983, p.223), it is no wonder that air traffic, too, has been growing by about 4% year after year (EUROCONTROL´s Performance Review Report 2006) and is predicted to continue doing so.

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[1] "The paper flight strip is a small slip that contains flight plan data about each controlled aircraft's route, speed, altitude, times over waypoints and other characteristics. It is used by air traffic controllers in conjunction with a radar representation of air traffic" (Dekker & Nyce, 2004)

[2] In a strip-less environment "parts of the flight plan information is presented [in electronical form] in the extended track label or in dedicated flight information lists" (Hering & Guibert, n.d.)

The interesting question, which due to space and topic limitations will not be discussed further in this study, is whether we want to increase air traffic at all? Is it necessary and if we deem it to be so, is it necessary enough given the moral and ethic responsibilities we have for sustaining our planet for future generations? Let us assume this question got the appropriate attention and traffic growth is what we are, with clear conscience, aiming for.

In order to create and maintain safety Air Traffic Controllers (ATCOs) have to make fast and at the same time safe decisions in an ever changing and shifting, complex environment. The more traffic they have to handle, the more decisions they have to make; thus the greater the time constraints on the safe handling of traffic. The purpose of this study is to get an idea of how Air Traffic Controllers are able to manage the intensive time constraints that come along with the growing traffic numbers they have to handle. Which strategies do they employ and which mechanisms do they rely on to save time? And what exactly do they use this time for?

Underlying Assumptions

When I put the general question of "how do Air Traffic Controllers create safety?" to a number of Controller colleagues, the first reaction was the statement "They don't!". That's why I feel urged to lay out my underlying assumptions here. In contrast to the common belief that "complex systems would be fine, were it not for the erratic behavior of some unreliable people …in it" (Dekker, 2002, p.3), this thesis takes an alternative position - that human operators, in this case Air Traffic Controllers, are vital for the creation and maintenance of safety. They are the ones who have the flexibility and creativity to adapt to the various situations that occur in our complex

systems and consequently can "negotiate between safety and other pressures in actual operating conditions" (Dekker, 2006, p.16).

Another assumption underlying this study is that safety is a social construct. A great deal of how operators "operate safely is a property of the interactions, rituals, and myths of the social structure and beliefs of the whole organization" (Rochlin, 1999, p.1558). Safety is not a property of a system, meaning that once it is put in place it remains and works. Rather it has to be created and maintained continuously by the human operators in the system (Hollnagel & Woods, 2006, p.347).

Thus I am focusing on the human operators and following the line of Klein and other researchers. I am not interested in defining what limits human performance, but I am interested in finding what competences help Air Traffic Controllers manage their jobs.

Literature

To increase safety researchers argue that it may be necessary to develop a completely new system or concept of Air Traffic Control (ATC) (Hoekstra, van Gent & Ruigrok, 2002, Rivière, 2004, Arvidsson, Johansson & Akselsson, 2006). Or that maintaining the current system and adding new technical features might improve safety (Rognin, Grimaud, Hoffman & Zeghal, 2002, Kaber et al 2006). Some authors also believe that to improve safety it is necessary to study the cognitive processes of Controllers (Shorrock, 2005, Averty, Athenes, Collet & Dittmar, 2002, Lee, n.d.). All these approaches are etic approaches, working outside-in, from the researcher to the Controllers. Nobody seems interested in hearing what the Controllers themselves have to say about safety and their work experiences.

Method

This study takes an emic perspective, that is, to let the Controllers speak for themselves and find out which concepts and processes they experience as important and worth relying on. Therefore, I chose the qualitative approach of formal, but unstructured in-depth interviewing. 8 controllers were each interviewed for 20-30 minutes after having given their informed consent. The interviews were done in English, so that the issue of translation did not arise. The transcription was done by me.

Analysis

Working through the interviews it became clear to me that ATCOs are very concerned about things that take up time, that they are in effect saving time for SOMETHING.

"You can have times when things are hard, the pilots don't listen, you can't get in contact with the people you want to get in contact as fast as you want to. Everything is just working against you" (P1)
"They [the strips] take too much time for nothing…" (P3)
"Two [persons] doing the job, so we have a little bit more time for concentrating on the traffic" (P2)
"Then (when you're nervous/not confident) you sit there and really have to check everything 3 or 4 times; but you don't have the time to do that…"(P2)

Table 1 - Saving Time for Something

First I thought they do this to have more time for making decisions, but this turned out not to be the case. So what is this SOMETHING they are trying to gain time for? What is so important that all other activities are arranged around it? And how do ATCOs achieve to manage their time accordingly?

Recognition-Primed-Decision Model

To make sense of the processes that inform the ATCOs' management of time and decision-making, I find it useful to work with Klein's Recognition-Primed-Decision Model (RPD-Model). This model was developed from and for naturalistic studies of decision-making.

The RPD-Model presents an alternative to the analytical, comparative decision strategies that emerge from laboratory experiments. These experiments lead to the standard advice that for making better decisions it is necessary "to identify all the relevant options, define all the important evaluation criteria, weight the importance of each evaluation criterion, evaluate each option on each criterion, tabulate the results, and select the winner" (Klein, 1999, p.102). In short decision-making is all about optimizing. Research in naturalistic decision settings, outside the laboratory, with experienced decision-makers (what distinguishes experienced decision-makers from novices will be explained below) shows that in time pressured situations there is hardly enough time for comparing each option, in a word for optimizing.

In naturalistic settings a different kind of evaluation seems to occur: "looking at one action at a time to see if it will work or can be made to work" (Klein, 1999, p.92), "evaluating each option on its own merits, even if we cycle through several possibilities" (Klein 1999, p. 20). This kind of evaluation is based on satisficing, which in comparison to optimizing, attempts to select the first option that works instead of trying to find the best strategy.

To find out whether or not an option will work experienced decision-makers employ "mental simulation[s], running the action through in their minds… If they spot a potential problem … they move on to the next option…until they find one that seems to work" (Klein, 1999, p. 21).

In the RPD-Model two kinds of decision-making processes get fused: "the way decision makers size up the situation to recognize which course of action makes sense, and the way they evaluate that course of action by imagining it" (Klein, 1999, p.24).

By sizing up a situation experts are able to recognize a situation as typical and familiar. Part of this recognition rests on their understanding of "what types of goals make sense (so the priorities are set), which cues are important (so there is not an overload of information), what to expect next (so they can prepare themselves and notice surprises)" (Klein, 1999, p.24). From "the typical way of responding in a given situation", experts can recognize the course of action that is likely to succeed in that situation (Klein, 1999, p.24). The process of Sizing Up a situation involves a constant, non-linear, intertwined comparison of those four elements against the dynamically evolving environment.

If the information available is not enough to clearly match a case or matches more than one typical case, more effort needs to be put into diagnosing the situation. This also is the case when standard expectancies are violated suggesting to the expert that the situation was most likely misinterpreted.

Once the situation is correctly sized up and the decision-maker has recognized a possible, and likely to succeed, course of action, he/she evaluates it by mentally simulating how it will play out. If difficulties are anticipated he/she may adjust the course of action or reject it and look for an alternative (Klein, 1999, p.26).

Below is the RPD-Model with the two stages of Sizing Up and evaluation of a possible action.

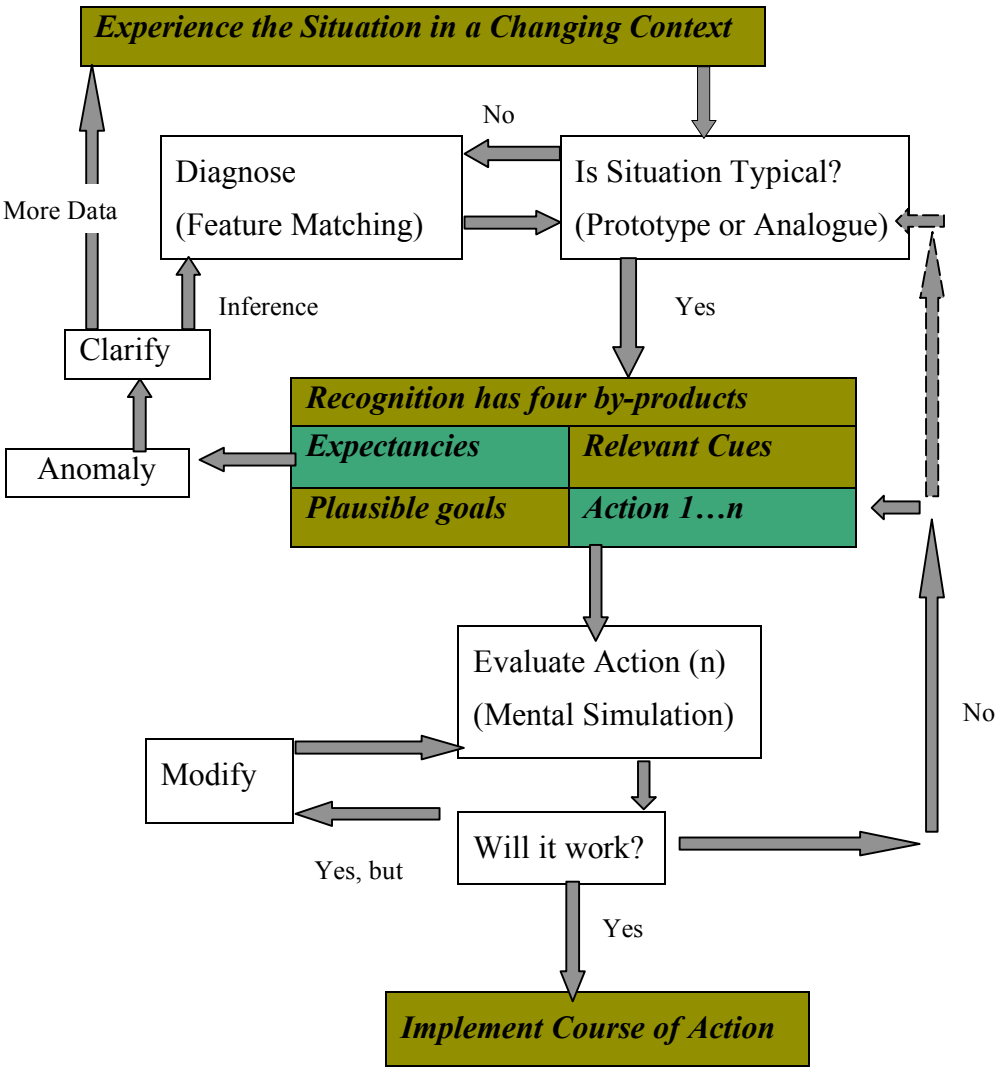

Figure 1 – Integrated Recognition-Primed-Decision Model

Naturalistic decision-making settings.

It seems obvious that ATC is an example of naturalistic decision-making. This is how Orasanu and Connolly define such events.

> Features that help define a naturalistic decision-making setting are time pressure, high stakes, experienced decision makers, inadequate information (information that is missing, ambiguous, or erroneous), ill-defined goals, poorly defined procedures, cue learning, context (e.g., higher-level goals, stress), dynamic decisions, and team coordination (Orasanu & Connolly, 1993 in Klein, 1999).

The ATCOs I interviewed confirm this match. It is further validated by my own experience working as an ATCO.

The moments in an ATCOs working life I am most interested in here are the times when traffic density within the controlled sector is high and consequently time pressure and the probability of complexity are high as well.

In those settings the stakes are high. If the ATCO makes a bad/unsafe decision (definition of a bad/unsafe decision see Table 5), which is not corrected, hundreds of lives may be in danger.

"that [Ueberlingen] could be a situation that could happen for us all" (P1)	
"You can't sit there thinking there are 200 people on that aircraft and 150 in that one, because, no, we can't do that. You shouldn't start thinking about this. You have to kind of push it back into the background, I guess"(P2)	High stakes in form of the great number of people that are sitting in the aircraft is ever present and needs to be dealt with in order to be able to do the job.
"we are all good controllers in this environment. And that also affects the way we work, because we have confidence in each other" (P4)	The controllers recognize each other as experienced and able to do the job/worth to be trusted with the job.

Table 2 - High Stakes and the Need for experienced Decision-Makers

The overall goal and procedures in ATC are relatively well defined, for example "maintain 1000ft vertical or 5 miles horizontal separation". However procedures and restrictions such as those laid down in Letters of Agreement[3] cannot alone guarantee safety. What insures safety in the dynamically changing setting of a busy sector is the ability of ATCOs to ensure an efficient flow of traffic. This must constantly be adjusted and renegotiated with one's own team and adjacent and subjacent sector-teams. In short, procedures need to be refitted to the context, because "procedures [alone] cannot guarantee safety.

"And sometimes I think they [pilots' priorities and controller priorities] don't really go too good together, because we want something and they [pilots] want another thing" (P2)	The priorities constantly need to be re-negotiated with the parties involved. In this case Controllers and Pilots.
"There are always funny people working everywhere, but I think when everybody has this willingness to try to understand the situation and to help to solve it in the best common interest for everybody then it's much fun to work."(P3)	Controllers have to work together with the Controllers of other centers around them. That requires a lot of team effort from all sides.

Table 3 - Teamwork in ATC

"Safety comes from people being skillful at judging when and how they [procedures] apply" (Dekker, 2006, p.157). Procedures often take "much experience to interpret" (Klein, 1999, p.161) and applying them successfully is a "substantive, skillful cognitive activity" (Dekker, 2006, p.157).

[3] Every two Air Traffic Control Units that work Areas of Responsibility that lay next to each other agree on general conditions under which aircraft have to be handed over. Those agreements are laid down in the Letter of Agreement.

Cue learning, referring "to the need to perceive patterns and make distinctions" (Klein 1999, p.5), often occurs in ATC. ATCOs learn to recognize certain traffic configurations that occur repetitively, and they also learn which cues point to differences in those patterns which suggest that previous solutions will probably not work this time.

"Because you just tried so many situations and everything is repeating, things you've seen before a little bit different angle, a little bit different climb rate, but it's more or less the same and you just know "ok, you have seen this, you do that and you did that" (P3)	The perception of patterns, of familiar situations.

Table 4 - Cue Learning/Perceiving Patterns

Stress induced by shift-work and the need for high concentration characterizes ATC work. Participant 2 describes it like this:

"Those days when it is really, really busy, maybe with some military exercise and you only get 15 minutes break and then you have to get up [back to the position] again and when the day is over you are really, really tired".

ATCOs often find themselves torn between a series of competing demands. Among these is the need to reduce traffic delays, maintain an efficient flow of traffic and at the same time ensure safety. The Controllers do not have a lot of influence on deciding the actual traffic numbers to be handled in a sector at any particular moment, this is flow-management's[4] task.

[4] "Air Traffic Flow and Capacity Management (ATFCM) is a service provided on behalf of Air Traffic Services (ATS) and Aircraft Operators (AO) with the following principal objectives: To develop and maintain the highest level of quality of ATFCM service on behalf of both its ATS and AO users within the agreed ATFCM policy and principles. For ATS their role is limited to the provision of flight plan data, the best utilization of available capacity, the smoothing of traffic flows and the assurance of protection against overloads." (Eurocontrol-CFMU Mission Statement)

For whatever reasons and pressures the sectors might get busy (definition of "busy" see Table 6). If and when this happens Controllers must tactically manage the traffic they are expected to work in the limited time available without losing the prescribed separation minimum of 5miles or 1000ft.

Here I will use the Recognition-Primed-Decision Model to elaborate how ATCOs succeed in doing this.

What is a bad/poor decision?
If we try to define a decision as bad/poor by looking at the outcome, we are relying on hindsight and the advanced knowledge it provides us with. Even if the outcome is unhappy it can turn out that the decision taken was the best one considering the knowledge available to the decision-maker at that point of time (Klein, 1999, p. 271). We need to understand "the information available to a person, the goals the person is pursuing, and the level of experience" (Woods et al. cited in Klein, 1999, p.273). If we judge decisions in that light it becomes apparent that each decision is the best that can be made in that situation with the information available. That is why I agree with Klein in the assumption that "simply knowing that the outcome was unfavorable should not matter. Knowing what you failed to consider would matter"; and I will use his definition of a poor decision: "A person will consider a decision to be poor if the knowledge gained would lead to a different decision if a similar situation arose" (Klein, 1999, p.271)

Table 5 - Definition of a Poor Decision

What is a busy situation?
Not busy, busy, too busy. Since these are concepts that are constructed subjectively at an individual and group level, it is impossible to find an external definition for them. They depend on the condition of the individual and the group the individual is situated in. For the purpose of this study I will consider a situation to be not busy if the time available is greater than the time needed to deal with the aircraft in the sector. The closer the values of time available and time needed get, the busier the situation. If the time available equals the time needed to handle the aircraft it is busy. This state can be stretched slightly by applying a more efficient kind of time management that allows for just some extra time needed. If that balanced state is exceeded and the time needed is greater than the time available it is too busy.

Table 6 - Definition of a Busy Situation

Recognitional decision-making.

Is the decision-making done by the ATCOs recognitional?

Klein and his colleagues argue that decision points are recognitional "if the options came from experience and were not consciously compared, and the decision maker selected the first action that was acceptable" (Klein, 1999, p.27). The first part of this sentence corresponds to singular evaluation; the second part to satisficing, upon which singular evaluation is based (Klein, 1999, p. 20).

Furthermore he describes certain situations in which people are more likely to use singular strategies (Klein, 1999, p.95): Those situations are time-pressured, the decision-makers are more experienced and the conditions more dynamic.

These characteristics suggest that decision-making in ATC is recognitional especially when, most of the time, the Controller is faced with a busy sector. My own experience supports this assumption. At work, the tendency is to go for the first workable solution I see. In busy traffic situations the search for an optimal solution can lead to

paralysis and is therefore not suitable. This process of satisficing, central to how Controllers do their work, occurs as Participant 2 explains, “Everybody here is focused on doing a safe job, not necessarily the smartest”.

Mental Simulation.

Do ATCOs employ Mental Simulation to evaluate a course of action?
Since I did not set out to answer this question, all I can do is speak from my own experience. I can say that, as an ATCO, I do simulate different possible actions and evolving scenarios before taking action. Due to lack of data, the present discussion will focus on other parts of the RPD model, the assessment of a situation and the recognition of a workable solution (making a decision).

Where from here?

From here I would like to do two things: One is to show how important the Sizing Up is for ATCOs and the other one is to argue that this process is the SOMETHING that Controllers save their time for. Some of the strategies and processes ATCOs employ to be able to save that time will also be described.

The Importance of Sizing Up a Situation

In order to create and maintain safety, ATCOs have to be able to make fast and safe (as opposed to bad/poor) decisions in ever changing dynamic situations to accommodate the traffic they are supposed to work without losing separation. To be able to do this they need to know the context in which they are making each decision. If you do not know which context you make a decision in it is impossible to at least have a chance to make a "right" decision. So they need to know at any time which situation they are dealing with.

We cannot know any situation at any time to its full extent due to our bounded rationality and due to our inability to predict the future. Nevertheless, if the decision-maker is reluctant to act due to uncertainty "the action will be delayed or will be overtaken by events as windows of opportunity close…Decision makers must be able to proceed without having a full understanding of events" (Klein, 1999, p.276).

What tends to substitute for complete or even adequate knowledge of a situation is the ability to size up a situation. This allows one to recognize a situation as familiar/typical and to feel able to make safe/right decisions. This only means that in this context or a similar one the same decision and course of action would be repeated, if the knowledge at hand is not radically altered.

The ability to assess and size up a situation gives the ATCOs an appropriate context out of which they can make decisions. That is why it is so vital for ATC.

Without Sizing Up ATC would not be possible!

ATCOs talk a lot about Sizing Up, using different words though:

"You're watching the situation and the possible situations that could occur within the next few minutes or maybe longer time " (P3)	= Sizing Up
"Maybe something is developing that shouldn't have been … but if you're alert it doesn't really matter that people forget to call you, because you can see what is happening" (P3)	Being alert = Sizing Up
"I think being able to listen in what the other guys are doing at the same time while you're doing your own job is a big part of the big puzzle to get everything solved" (P2)	Listening around gives information that make the Sizing Up more precise
"Very important, yes! To have that extra time [for scanning for unusual things]" (P3)	= Sizing Up
" That (the ability to hear what is going on around you) goes away when you're tired, then you focus more on your own problems… Of course that happens when you're really, really busy as well… because then you don't have time to start listening to the others" (P2)	Focusing more on own problems = Sizing Up becomes more difficult

Table 7 - Controllers talking about Sizing Up

Processes that make Sizing Up possible

How do ATCOs make time available to size up and what processes and mechanisms do ATCOs employ to be able to do this, that is, to assess the situation they are facing as accurately as possible?

Those two questions are deeply interrelated. If the ATCOs are able to size up a situation as accurately as possible, the probability that the first action chosen is indeed workable is greater, thus attention can be taken away from one "acute" problem and dedicated to further Sizing Up. Recognitional decision-making enables ATCOs to do

fast/safe decision-making with less time needed for each decision. This frees up time for further Sizing Up and thus for further recognitional decision-making (See again page 9 bottom).

To save time there are routines Controllers learn to use the technical system - which buttons to press, where to look for necessary information, how to make certain inputs. These routines make it possible to carry out those tasks without dedicating a lot of time and attention to them, so that the additional resources can be focused on Sizing Up.

When new systems are put in place the routines often become degraded. When asked why the capacity would go down when the new system will be put in place and will have to be worked with, one participant said:

> Because you are going to use a lot of your capacity on you new routines and learning new systems. The new routines are going to, just to know the phone panel and to know which menu buttons to push, so I think in the beginning for a long time you will not be ok with having really heavy traffic in your area and still fast know to put vectors on two aircraft. (P5)

The “little” tasks take up too much time and attention, which diverts time and attention from the necessary Sizing Up.

But what about saving time by working from an as accurate situation assessment as possible?

The recognition-primed decision-making that occurs in busy ATC settings would not be possible without experience. Novices, faced with unfamiliar situations, are less likely to use this type of decision-making (Klein, 1999, p.96).

Only experience makes it possible to apply the RPD-strategies (recognizing situations as familiar and recognizing workable courses of action) and thus being able to make fast, accurate decisions.

Experience

How does experience help ATCOs? What does it equip them with?

Asked how experience helps him, one participant answered:

> I think for one thing you're very fast in analysing a situation and you have a lot of tools to use for solving the problems" and "You just tried so many situations and everything is repeating, things you've seen before a little bit different angle, a little bit different climb rate, but it's more or less the same and you just know 'ok, you have seen this, you do that and you did that'. You don't have to think and you don't have to invent solutions, you have solutions and you also learned from the bad solutions you have chosen how not to get in trouble, how to make things work easy even if they don't go as planned then you won't get into trouble, like what you do when you're inexperienced sometimes; Sometimes you can get into trouble because things go a little bit differently. And you always have, because you know so many solutions, you have plan A, B, maybe you even have C, D, and E. Then you just do something else. If somebody calls and changes your plan it doesn't kick you or anything. (P3)

What this interviewee is talking about is the role experience plays in Sizing Up. When you do not have to think about or invent a solution (a recognitional way of decision-making), Sizing Up is both more efficient and economic (in reference to time). The ability to recognize situations that he has seen before and the many tools

and plans he has for solving recurrent problems shows the important role that pattern-matching and the ability to improvise plays in Air Traffic Control work.

Klein (1999, p.148/149) states that experts are able to see certain things that are invisible to everyone else:

- Patterns that novices do not notice.
- Anomalies- events that did not happen and other violations of expectancies.
- The big picture…
- The way things work.
- Opportunities and improvisations.
- Events that either already happened (the past) or are going to happen (the future)
- Differences too small for novices to detect.
- Their own limitations.

Pattern-matching.

Experience enables experts to recognize patterns and the typicality of a situation, which people who are not experts have trouble with (Klein, 1999, p.150). This ability makes it possible to apply recognitional decision-making and to save time. The quote above illustrates that ability. Further it makes it less likely that experts fall victim to information overload (Klein, 1999, p.152).

The way things work.

Experts "have mental models of how tasks are supposed to be performed [rules and regulations], teams are supposed to coordinate, equipment is supposed to function"

(Klein, 1999, p.152). That gives them an idea about what to expect and, as a result, they can size up a situation much more accurately than novices can, which also saves time. Experts are better than novices in knowing events that either already happened (the past) or are going to happen (the future). These are all important features in Sizing Up.

Knowing and sharing the team's mental model "lets the expert anticipate what the other team members will need and will be doing" (Klein, 1999, p.153). It is one way that helps forming expectancies about the pattern and shape of future events and this saves time.

"We have a common agreement in the way to solve traffic problems more or less, and it's very rare that we have misunderstandings or even argument concerning how to do" (P7)	There is a common understanding of how things should be done, which reduces the need for time-consuming coordination efforts
"usually there is a lot of silent coordination or, you know, you don't have to talk, to tell your planner what to do all the time, but a lot of the job is just done" (P5)	
"if I work with the team that I usually work with, then I would say the capacity is higher than if I work with others" (P4)	They know their teammates and know what they can expect from them
"in understanding what to expect I also prepare myself for what I will get and means also that I can rely on them to accept the traffic that I give them" (P4)	

Table 8 - Knowing the Mental Model of Team Coordination

ATCOs would even like to include pilots and controllers from other centers into the working team. They would like to know more about what they can expect from pilots in the different passages of flight[5]. They would also like to know more about other centers and their equipment and way of working. This would again increase the chance that the Sizing Up Controllers do is appropriate.

"… getting in a cockpit for us to see what they are doing from takeoff to cruise to landing all the things they have to do, so that we don't bother them at the wrong time" (P2)
"it's very important to see the equipment to understand a little bit how the other people[in other centres] work and what are the limits of their performance." (P3)

Table 9 - Knowing the Coordination Partners

[5] The passages of flight meant here are departure, cruise and approach.

"Experts also have mental models of equipment…They know enough about how their equipment works to interpret what the system is telling them" and where it may mislead them (Klein, 1999, p.153). In Copenhagen ACC the system has not been fundamentally changed for about 20 years. That is the reason why the ATCOs there like to work with the system and trust it even though it is not always reliable and tends to breakdown.

"The fallback we have is ok and when you tried it a lot of times it doesn't really scare you" (P3)	Because of the regular breakdowns of the main system the ATCOs have to work with the fallback system relatively often, so that they get to know its abilities and limits well. They know what to expect from the fallback system.
"I learned what to do in the hard way, but I trust it" (P6)	
"In that way we know that we can work with the system. We know that there are not that many errors known to us in the system" (P4)	They know what to expect from the system they are working with.
"it's been tested quite well for almost 20 years now and everybody knows its weaknesses. And that's the whole point. We know what not to do and if something fails we know what to do to prevent it from really breaking down" (P6)	

Table 10 - Mental models of the System

Another feature that makes expectancies easier to predict are the rules and procedures that lay down how a task should be performed. Since it takes a lot of interpretive work and each individual does that differently, this only works in teams where there is in place a shared understanding of these rules. Especially in very busy situations when the Sizing Up is degraded, participants appreciate the predictability-giving effect of rules:

Then "everything has to be a bit more standardized… because then everybody knows what rules to stick to…" "You won't get some unexpected things" (P2).

Anomalies- events that did not happen and other violations of expectancies.

Since the decision-makers know what they can expect and how situations normally would evolve, they can recognize when their expectations are violated or a pattern is broken (Klein, 1999, p.151). This ability buys them time and serves as a safety feature. It helps them to recognize that a situation is actually not a typical one and this triggers efforts to come up with another, non-typical solution to the problem right away. It is also less likely then that they have to revise or revisit their decision again. Not surprisingly, the "greater the violations and the more effort it takes to explain away conflicting evidence, the less confident" they feel about their diagnosis (Klein, 1999, p.92).

While "laboratory studies often find that naïve subjects show confirmation bias" (Klein, 1999, p.297), Shanteau argues that experienced decision-makers do not fall prey to such bias. The question emerges; which kind of information does trigger for experts a revision of assessment and plans and which information does not? This question cannot be answered here. However, the evidence I have for Air Traffic Controllers supports Shanteau's claim. The interviews suggest that experienced ATCOs take into account variance and discrepancy when they evaluate their actions. One participant confirmed this:

"Maybe something is developing that shouldn't have been" and "… expecting the worst sometimes … and it's a little bit thinking all the time what possibly could go wrong" (P3).

Their own limitations.

"Experts are not only better at forming situation awareness and seeing the big picture[6], but they can detect when they are starting to lose the big picture. Rather than waiting until they have become hopelessly confused, experts sense any slippage early and make the necessary adaptations" (Klein, 1999, p.158). This ability serves as a safety feature in ATC. The participants in this study notice when they are in a condition that makes it more likely to fall behind and they adjust their decisions so they can still cope with the traffic safely.

"I tend to make things easier for myself. Thinking "I could give him this direct track, but I'm not really prepared to think about the consequences of this turn, I haven't really thought about traffic over here that could be conflicting"(P6)	There is no capacity for a renewed Sizing up with the new route taken into consideration, he decides to stay with the Sizing up that was already done for the present route of the flight.
" if I'm tired I have to be more careful about what I do, for instance I won't be having the planes too close to each other, I put in an extra margins or an extra buffer" (P4)	
"It's very important that you have to, while working, be able to just step aside and look at yourself and look at your situation" (P8)	

Table 11 - Adjusting Performance to own Limitations

[6] The "Big Picture" refers to the knowledge experts get of a situation by Sizing Up. They know what most likely happened in the past, have an idea about the goals that make sense, the cues that are important and how the situation will most likely evolve.

Experienced Decision-Makers

What is an expert/experienced decision-maker in ATC?

In many professions, like firefighters or pilots, a new colleague gets integrated in the team where there is hierarchy and expert decision-makers are at the top, the head commander in firefighting or the captain in the aircraft. Novices can learn the ropes without having to make important decisions on their own. After gaining experience they climb up the ladder and eventually become expert decision-makers themselves.

> Dreyfus and Dreyfus (1980, 1985) argue that professionals move through five stages of career development which they labeled 'novice', 'advanced beginner', 'competent', 'proficient' and 'expert' … According to Benner (1982, p.403), 'This person [advanced beginner] is one who has coped with enough real situations to note the recurrent meaningful situational components.' Advanced beginners start to differentiate situations but still have great difficulty distinguishing the important from the unimportant. Competent professionals have usually been in practice three to five years. These professionals can organize and plan activities; they are consciously aware of the plan and feel they have an ability to cope with unpredictable situations (quoted it Daley, 1999).

Ideally a newly checked-out Controller should be a competent professional, one who can cope with unpredictable situations. However, in ATC the new colleague does not have 3 to 5 years to gain that kind of experience. After ca. 1½ year of simulator and On-the-Job Training (OJT) they get checked out. This short amount of time to gain experience is made possible through the high exposure to different situations in the simulator, "which sometimes can provide more training value than direct experience" (Klein, 1999, p.43); They are also exposed to high traffic density through different real-life traffic situations during OJT training. After their check-out they are fully

responsible for all decisions they take and for the development of their own experience.

To be able to extend their experience base and move from advanced beginner to expert as quickly as possible, ATCOs apply "Expert Learning" from very early on. Klein identified a number of ways that experts in different fields learn (Klein, 1999, p.104):

- They engage in deliberate practice, so that each opportunity for practice has a goal and evaluation criteria.
- They compile an extensive experience bank.
- They obtain feedback that is accurate, diagnostic, and reasonably timely.
- They enrich their experiences by reviewing prior experiences to derive new insights and lessons from their mistakes[7].

[7] The difficulty of learning from experience due to the complexity and interrelatedness of situations leading to the problem that we often cannot clearly see a link between cause and effect (Klein, 1999, p.280) is acknowledged here, but will not be further elaborated due to space and topic limitations.

The participants in this study apply many of those ways to extend their experience:

" I think it's important to rethink these situations (potential of incident), to learn and to prevent them the next time" (P3)	Prior experiences are thought over as to incorporate new insights into the experience base so they can be applied the next time a decision needs to be made.
"if there has been an incident, we (military pilots and controller) take up that case and go through what happened and then ask questions about how come that it happened this way" (P4)	
"If you had a bad experience, or you had a near miss or you just didn't see something on the radar, on the strip table, just thinking a lot about what could I have done different?" (P6)	
"each time you do have both a minor or major mistake and again, even though it doesn't end up with a kind of failure or something like that, you will consider what to do the next time" (P7)	
"twice a year they send out a note with suggestions to improving the traffic flow and how to save each other problems" (P6)	Experiences get shared among the colleagues so that everybody can learn from mistakes (vicarious learning).
"just to discuss what went wrong and what was good and what can we do better next time" (P6)	
"Sometimes when you just make a decision to solve a conflict it just causes you more problems, because you turn him and you create another conflict with another acft and it would have been easier to turn left instead of right and then when you make the right decision you can see afterwards that that was a good decision instead of just creating problems for myself or other people." (P6)	They are obtaining feedback from their decisions right away and incorporate this feedback into their experience base.
"if you're taking the wrong decisions, which one was going first and you have to do a lot of turning and spacing where you afterwards could see "if I just took this one first, I wouldn't have had to work so hard" (P7)	

Table 12 - Ways of extending Experience

Conclusions and Implications

In this study I identified the Sizing Up of a situation as being the SOMETHING that Controllers arrange their time around and discussed some of the necessary conditions that make Sizing Up possible. Since Sizing Up is so important, because it makes recognitional decision-making possible, some of the attitudes Air Traffic Controllers have regarding the computer system they work with become more intelligible. When Controllers resist technology change this is seen as "proving" how conservative Air Traffic Controllers are as a group.

This study tried to show that a stable environment is one that enables successful, competent ATC work. We saw that ATCOs can work with almost everything (even breakdowns and fallback system). This does not mean however that it is irrelevant which systems ATCOs have to work with. What needs to be acknowledged is that any change will result in a temporarily decrease in capacity due to the need for staff to build up operational routines from scratch again. Routine tasks to retrieve information from the system and to feed the system information should be kept to a minimum to make sure that ATCOs have as much time available as possible for Sizing Up.

Another conclusion, that might seem obvious, is that overload/ too busy situations need to be avoided. Then Sizing Up gets so far degraded that doing a safe job is not possible anymore. This does not necessarily mean that work will result in unsafe conditions but the probability increases. Further research should be done in regards of how the labor situation of individual Air Traffic Controllers can be redesigned to prevent overload situations. Simulator training for Air Traffic Controller trainees should be continued and, where necessary, improved because it exposes trainees to many different traffic situations and thereby enables them to gain experience quickly.

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