Working on the edge of performance: the implications of automation

by Dr Tamsyn Edwards and Dr Barry Kirwan

"It starts off by just falling behind a bit. So you might just be a few steps behind what you're supposed to be doing and if that builds up too much then you will get to the point where you start to lose the picture"

"You realise you're late on the situation. 'Why am I late on that situation?'"

Dr. Tamsyn Edwards is a Senior Human Factors specialist working for NATS. She is currently undertaking work to determine ways to identify and mitigate the causes of controller fatigue and how to maximise human performance through the design of new systems. Tamsyn is also a trained Human Factors investigator of air traffic control incidents. Prior to joining NATS in 2013, Tamsyn completed a PhD from the University of Nottingham in collaboration with EUROCONTROL, which investigated interactions between multiple, co-occurring factors (such as workload, fatigue, situation awareness) and the associated impact on controller performance.

Within ATC, automation has already had a big effect on air traffic control systems and working practices. And all signs point to the amount of automation increasing – we're all aware of the predicted increases in traffic by 2020, and with the addition of the deployment phase of SESAR initiatives, it seems likely that controllers will be working with progressively more automated systems. However, to take a look on the negative side, automation that has not been designed specifically with impact on the human in mind can drive workload upwards, create fatigue, and negatively affect the controller's mental 'picture' by reducing situational awareness, potentially leading into a myriad of problems and, ultimately, losses of separation.

These external pressures can push controllers to the edge of their performance. Stories shared between air traffic controllers highlight the subjective experience of reaching performance 'limits': *"If you have aircraft that isn't listening and you're busy…it may be the extra thing that sends you over".* The control situation is not comfortable, but performance is still maintained. But what's it like to work on this edge, and what are the indications that a controller is working to their limits? Is it possible to use this information to support the introduction and use of control systems with increased automation? We were fortunate enough to be able to talk with 23 controllers at the Maastricht UAC (MUAC) about their experiences of working at the edge of performance and here are some of their stories. It must be noted that these interviews were conducted a while ago, and the current automation tools in MUAC are greatly improved and seen as an asset by the controllers. Nevertheless, such comments and experiences give us pause for thought in the race to automate.

Getting close to the edge – the use of 'indicators'

Controllers told us of different experiences depending on where they were in the human performance 'envelope'. On a day-to-day basis, performance can be comfortably maintained at an exceptional standard. However, if demand (due to task or external factors) increases, there may be some discomfort, but accompanied by a sense of *"it's just part of the job, it's what you get paid for".* However, if demand increases further, a negative effect on performance may set in. The controller may begin to fall behind the traffic: *"It's something that will build up and you miss one…and then okay maybe you miss another one or two or you're confused as to who called you. Sometimes that happens and it'll go back down again and there's no problem and sometimes it will keep rising and you start to lose the picture."* According to the human performance envelope

theory, this point represents the performance limit, the edge of safe performance, after which there is the danger of a performance precipice, e.g. the controller 'losing the picture', with the heightened risk of a loss of separation, depending on traffic circumstances.

Controllers say that they can identify when they, or their colleagues, are nearing their performance limits through identifying specific 'indicators': *"The indicators occur en route to losing control or moving towards or even crossing the limits [of performance]. So it's not like the limit is here and you see the indicators and then, suddenly, bang, you run over. The indicators are part of it on the way down to losing control."*

Controllers automatically took notice of these indicators *"you don't think about…I just do it like it's a brain process that isn't conscious,"* and monitored their own personal indicators as well as indicators they observed in their colleagues: *"…We work closely together, we monitor each other, whether they're on the ball or whether they're tired, whether they're distracted, it's part of the job and you make allowances."*

But what exactly are these indicators? They can be internal (a feeling) or external (observable). Internal indicators may alert the controller to specific state or negative influence on performance: *"I know that when I start thinking, 'Oh it's going fine' I've learned that I force myself to tighten the bolts and to really pay extra attention".* On the other hand, external indicators are observable in others. They can be:

- **Changes in personal performance:** *"If you are a coordinator controller, you follow what the executive is doing and if it's an easy situation and the obvious solution is not applied straight away, it can trigger a little alarm in your head."*
- **Behavioural and physical changes:** *"You see it coming, you see them getting nervous, you see them talking faster."*
- **Compensation strategies – change of control strategy to maintain performance:** *"When somebody is being extra careful, I suppose that it's because they feel that they need to be extra careful."*

Specific indicators for Specific Factors

Although all controllers were familiar with the use of indicators, for some it was difficult to specify those they used on a daily basis because the process is usually automatic: *"It's in you and you just have to listen" "I think for yourself it's most probably more difficult, you see it much more easily for other people than for yourself."* However, after discussion all controllers were able to identify the indicators they used to recognise when they or a colleague were reaching the edge of performance. Indicators were associated with factors such as low and high workload, fatigue, and reduction in situational awareness (SA), all areas which automation can influence. They included observable indicators seen following changes in control strategy which had occurred as a response to the approach of performance limits. The ones listed below are not meant to constitute an exhaustive inventory, but rather to serve as examples.

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High workload

"It's almost excited because there is more traffic coming. It's a different situation if someone is already in a complex situation, you realise he is falling behind"

Table 1: Internal indicators of high workload

Category	Indicators
Cognitive changes	Don't know the next steps Increased focus Calls are a surprise
Changes to control	More reactive No back-up plan Future plan reduces in minutes ahead

Table 2: Observable indicators of high workload

Category	Indicators
Perception changes	Can't talk to executive/ executive doesn't hear you
Performance changes	Miss actions Can't see simple solutions Overlook aircraft
Verbal cues	Speaks louder Speaks faster
Compensation strategy: Control strategy changes	Less prioritisation on efficiency and more on safety Back to basics Defensive controlling Continuous talking so as not to be interrupted

Low workload

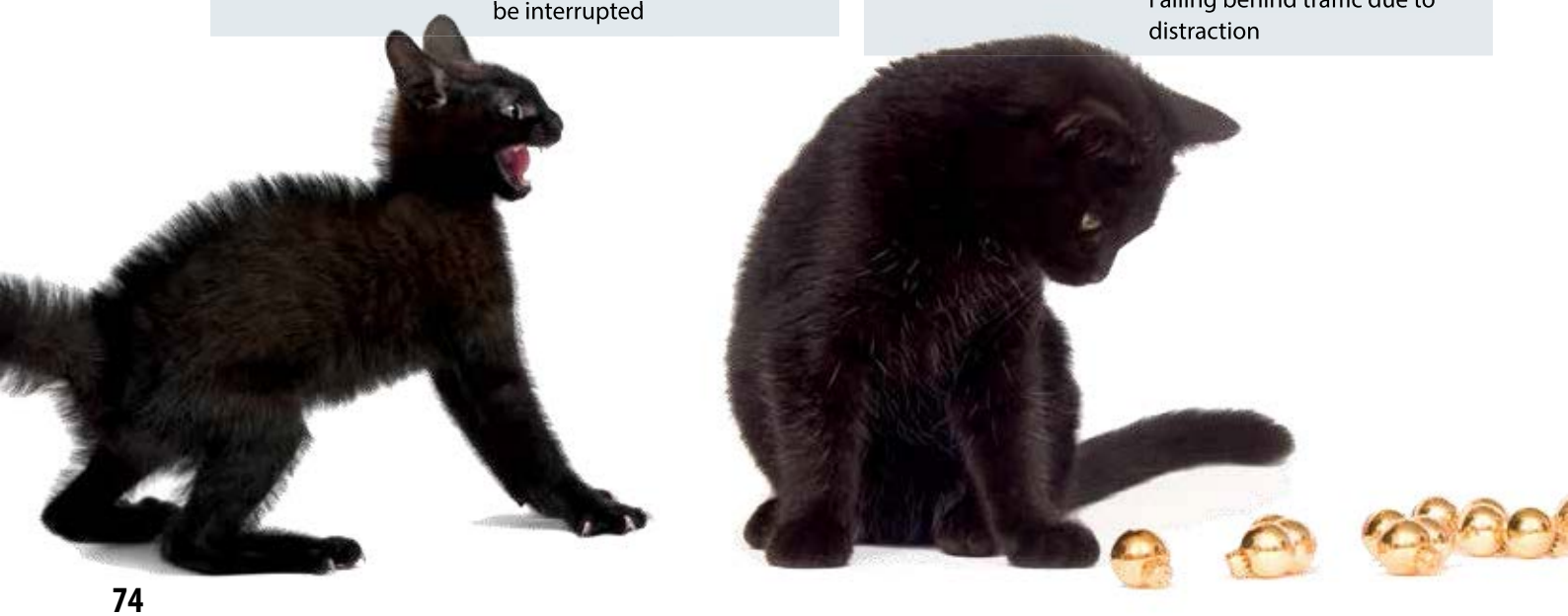
"In low workload, there's nothing to do so you start doing other things, boredom becomes an issue and then you start talking or having a chat or doing whatever and it's, yeah, you can miss things." One indicator mentioned was leaving a problem to develop for longer or creating complex situations to reduce boredom. If subsequently distracted or suddenly busy, this can create an unfavourable situation.

Table 3: Indicators of low workload internal to the controller

Category	Indicators
Cognitive changes	Pays less attention Easily distracted Reduced awareness
Changes to control	Leaves situations to develop for longer Tries to create more complex situations Less safety margin
Subjective feeling	Bored Relaxed

Table 4: Observed indicators of low workload

Category	Indicators
Visible cues	Sitting back in the chair Talking to colleagues
Performance changes	Overlooking an aircraft Forgetting an aircraft Falling behind traffic due to distraction



Fatigue

"Controllers tend to be more relaxed when they're fatigued, giving clearances without giving a rate of descent, but assuming that the aircraft will descend or the aircraft will pass."

"If I'm tired my concentration levels are low and I might miss a few things, maybe I don't hear the pilots or I don't monitor my own readback."

Table 5: Internal Indicators of fatigue

Category	Indicators
Cognitive changes	Slow Increased assumptions Not as sharp
Changes to control	Less flexible Slower to solve problems Don't see, or take longer to see, a solution
Subjective feeling	More effort to control Don't want to work busy traffic Not comfortable

Table 6: Observed indicators of fatigue

Category	Indicators
Verbal	Slower speech
Teamwork	More discussions with coordinator
Performance changes	Multiple, small mistakes, 'sloppy' Overlooking aircraft, Mixing up call signs Forgetting / surprise
Compensation strategy: Executive Controller (EC) changes control strategy in response to feeling fatigued	Conservative control Simple controlling, easy solutions Increased safety buffer in use
Compensation strategy: Coordinating Controller (CC) changes control strategy in response to noticing EC is fatigued	More proactive – solve issues prior to reaching EC Double-checking of clearances

Situational Awareness

Under high demand, the reduction of SA was reported to be progressive: *"It starts off by just falling behind a bit. So you might just be a few steps behind what you're supposed to be doing and if that builds up too much then you will get to the point where you start to lose the picture."* With low traffic levels, the loss of SA was more rapid: *"We sort of relaxed, 'Oh, it's done now', both of us had forgotten about it [the aircraft]."*

Compensation strategies from the EC attempt to make the situation safe when awareness is degraded. Conversely, compensation strategies by the CC are tactical and appear to facilitate the EC in rebuilding the picture.

Table 7: Internal Indicators of reduced SA

Category	Indicators internal to the controller of losing the picture	Indicators internal to the controller having lost the picture
Cognitive changes	Difficulty prioritising Thinking whilst giving the clearance Tunnel vision/hearing	Lost awareness Everything a surprise No plan Can't see a solution
Changes to control	Reduction of the scope of future planning	Reactive control
Subjective feeling	Under-confidence	Panic

Table 8: Observed indicators of reduced SA

Category	Observable indicators of losing the picture	Observable indicators of having lost the picture
Visible cues	Slow at task	Zig-zagging head movement of where to look 'Blacked out' / silent
Performance changes	Running behind Time of planning ahead degrades Missing calls	Unsafe clearance Unexpected decisions Jumping from one aircraft to another Don't know who's calling

Each of the 23 controllers interviewed described all the indicators in Tables 1-8 as ones they used, so these appear to be representative. Some other indicators were used only by one or two controllers. However, these differences provided a valuable learning opportunity: *"I've got my own indicators, but if everyone else has too, it would be interesting to know what they were".*

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The importance of self-awareness of indicators

It was apparent that indicators can play an important role in maintaining safety in air traffic control. They were also a source of feedback about oneself and one's colleagues so that awareness of them is likely to result in modified control strategies: *"…it's that point [of recognising something is wrong] where you have to, well in my opinion you have to change the way that you're controlling the traffic."* However, a key point that was raised was about individual awareness of markers: *"I'd say 300%, if you know that you're not on top form today then that's fine, just adapt your working style and you'll get through the day…if you don't recognise it and you're still trying to work as you usually do, then it might end in tears."*

Automation and performance indicators

But what effect does automation have on these indicators and awareness of them? With the growth of automation, some indicators learned through previous experience may be lost. One example of this was a controller who was occasionally reminded about excessively rapid speech: *"It's getting busy… you start speaking fast and then somebody says "Say again" and then that's it, you have a hint. 'Okay good, I have to slow down because I was not aware that I was speeding up my transmissions because of the amount of traffic'.* You slow down and everything's fine again." However, with the introduction of CPDLC / data link, the relevance of this indicator as a trigger for a change in control strategy could be lost.

New working methods may need new indicators, but these need to evolve and emerge, so there may be a vulnerable period in the early stages of change without any available 'warning signs'. But awareness of this risk helps. By gaining a greater understanding of what indicators may be lost, controllers can be ready to identify and share new ones and new coping strategies. By integrating these activities with the process of introducing automated systems, we can mitigate an issue which has plagued many deployments of automated systems and achieve a more successful implementation of automated systems in ATC.

POST-SCRIPT - around the time of writing this article, an international workshop convened seventy Human Factors professionals from across the entire Air Transport industry at EUROCONTROL in Brussels in order to identify the top Human Factors issues for aviation safety. The top three included Automation and the Human Performance Envelope. More information can be found at: **http://www.optics-project.eu/?p=776**