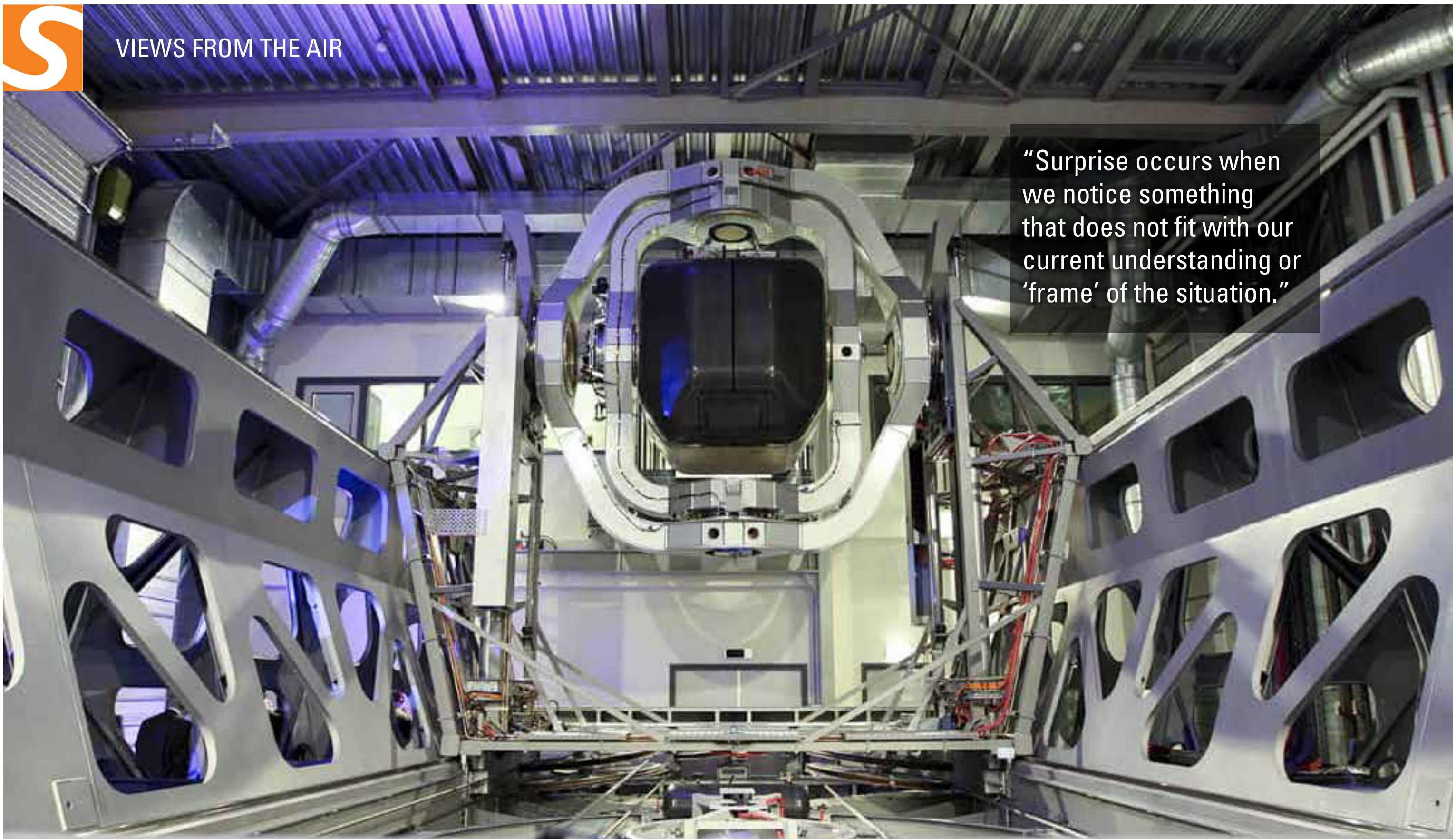

KEEP CALM AND REFRAME: ESSENTIAL ELEMENTS OF DEALING WITH SURPRISE

Over recent years, research in the Netherlands has helped to understand the nature of surprise in the flight deck, and has evaluated interventions to help pilots to respond in the best way possible. In this article, **Annemarie Landman**, **Eric Groen**, **René van Paassen**, and **Max Mulder** outline some of their key findings and insights on training and the management of surprise.

KEY POINTS

- **Surprise is a natural trigger to adjust one's understanding or mental 'frame' to the current situation, but such 'reframing' can be severely impaired under stress.**
- **A minor surprise can already significantly impact pilot performance, eliciting responses which are guided by reflexes rather than analysis of the situation.**
- **Unpredictable, variable, and explorative training can help build a proper repertoire of frames and skills that are resilient to surprise.**
- **Self-regulatory methods, such as surprise-management procedures, can help with 'recovering' one's brain after a surprise.**

Surprise occurs when we realise that our view of the situation turns out to have been erroneous, often leading to a reappraisal of past events to regain a consistent view. Surprise has been identified as an important contributing factor to loss of control in-flight (LOC-I) events, as it may impair or delay a crew's adequate response to maintain control of the aircraft. A surprise involving a sudden threat signal will cause stress, in which case a possible response is also commonly assocated with what is known as

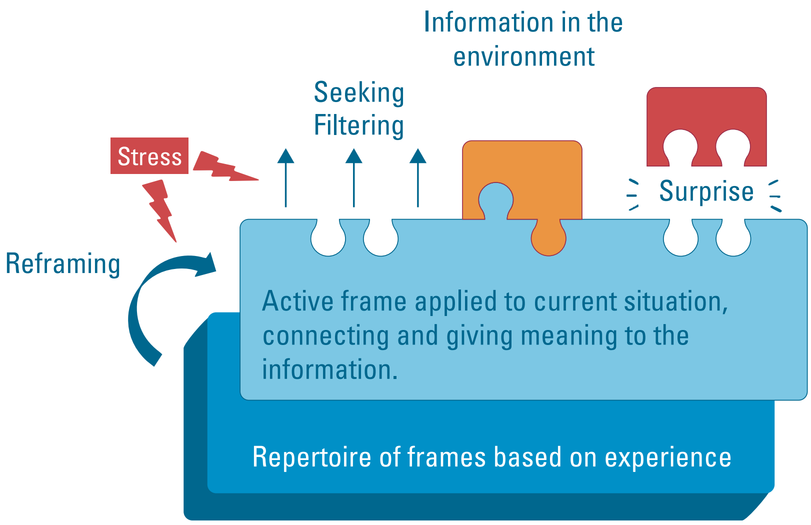

Figure 1. Schematic representation of the 'reframing model', showing that surprise arises when a piece of information (illustrated by the red puzzle piece) does not match the active frame.

'startle'. Aviation safety authorities have issued recommendations to take surprise into account in flight crew training. A joint research team of the Faculty of Aerospace Engineering of Delft University of Technology, and the Human Performance department of TNO (both located in the Netherlands) investigated the effectiveness of various training interventions aimed at improving pilots' abilities to deal with surprise. In this article, we share the most interesting findings, hoping that these provide useful insights to those working in any domain where surprise management is important.

Conceptual Model of Surprise

We created a conceptual model (Landman, et al, 2017a) to illustrate what happens in the brain when one encounters a surprising situation that is also stressful. A simplified version of the model is depicted in Figure 1. It uses 'frames', where a frame can be seen as a coherent set of expectations, rules and responses applicable in a certain context. Surprise occurs when we notice something that does not fit with our current understanding or 'frame' of the situation. Based on past experience, we have built a repertoire of frames of how things ought to work and what we can expect to happen next. These frames allow us to focus directly on what is important (i.e., attain situation awareness), make judgments, and select appropriate responses. Receiving information that does not fit the prediction from the current frame should trigger surprise: an alarm which signals that there may be a problem with our frame. We may need to adjust our frame (i.e., 'reframe') by collecting additional information and combining this with what we know (i.e., our repertoire of frames).

Reframing can be difficult by itself, but it is even more difficult under stress. Stress impairs the guidance of attention that frames provide (the 'seeking and filtering' in Figure 1), so that we can become more or less 'frameless'. We may start to misinterpret or completely miss relevant cues that would be very clear to us when interpreted within the proper frame. It can suddenly become more difficult to see things in context, to set proper priorities, and to focus on what is important. Such cognitive issues may result in haphazard actions or indecisiveness, the latter being known as 'freezing' in common language. The failure to meaningfully integrate incoming information in a frame further increases stress, which further hampers reframing. This means that our brain can become caught in a downward spiral, which can be labelled as a 'brain stall'. Our research focuses on the interaction of stress and reframing, to find ways that may help pilots 'recover' their brain.

"Introducing unpredictability and variability into training can improve pilots' reframing skills, and help them better manage surprising events."

Effect of Surprise on Stall Recovery

In a simulator study (Landman, 2017b) we validated the conceptual model by investigating how pilots respond to a surprising event in terms of stress and behaviour. Twenty commercial pilots practised recovery from an aerodynamic stall on a medium-sized twin jet in the moving-base Desdemona simulator (see photo on page 44). After the training session, they were exposed to a test, which included one unanticipated (surprising) stall, and one announced (unsurprising) stall, both at low altitude. Although the surprising stall was still likely much less surprising than a similar event would be in reality, we already observed some interesting changes in pilot behaviour. Generally, the pilots were less likely to apply pitch trim, and were more focused on rolling wings level in the surprising stall, which sometimes led to pilot-induced oscillations when the airspeed was still too low for the ailerons to be effective (Figure 2). The surprising stall was also rated as more mentally demanding than the anticipated stall, possibly due to the extra effort required for reframing. There was no difference in experienced stress, which was likely due to the safety of the simulated setting.

Building Experience Through Unpredictability, Variation and Exploration

Given that even moderate changes in expectation affect selection of the correct frame and performance in surprise situations, how can we prepare pilots for surprises? In a further study (Landman, 2018), we found that introducing unpredictability and variability into training can improve pilots' reframing skills, and help them better manage surprising events. Ten commercial pilots trained a series of manual flight scenarios with controllability issues in a variable order, in various contexts, and without information on the scenario. Ten other pilots (the control group) trained the same scenarios, but in a structured order, in the same context, and with information on the type of scenario trained. When both pilot groups were confronted with a problem that required the application of previously

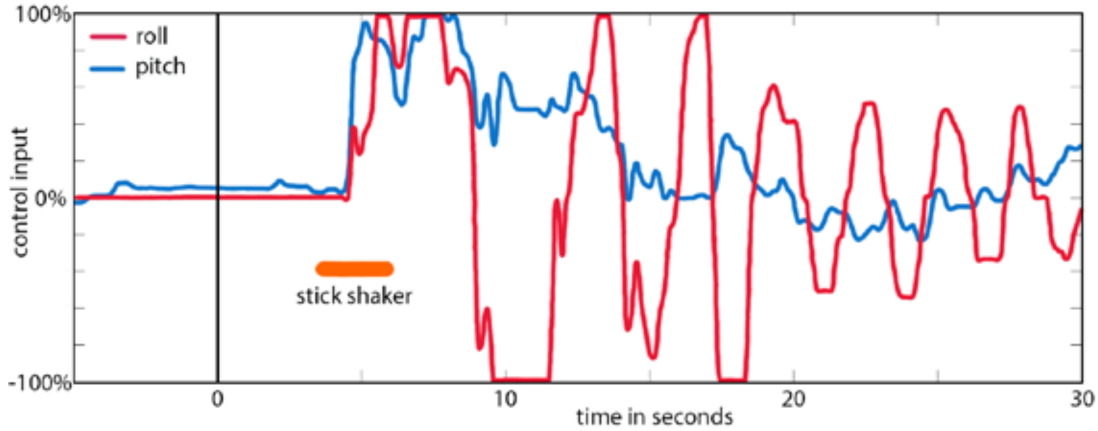

Figure 2. This plot shows the roll oscillations (red line) induced by a surprised pilot in response to an unanticipated stall warning.

learned skills in a new manner, pilots who had received the variable and unpredictable training outperformed the control group. This finding underlines the hypothesis that we construct the best frames when we experience situations with variations which are also surprising. When events are too consistently trained in the same context, or in the same combinations, we may develop a limited, 'rigid' frame for these events. This may cause confusion when the events occur in a divergent manner.

"Exploratory training can optimise a pilot's understanding of autopilot logic."

In a further study, which is to be published, we demonstrate that exploratory training can optimise a pilot's understanding of autopilot logic. In exploratory training, one learns new information by trying out different potential solutions to problems. We gave 45 general aviation pilots a theoretical course on autopilot functions, and then trained them in a Piper Seneca model in the Simona simulator (Figure 3). In this simulator session, different autopilot failures were introduced, and for each failure, the pilots were asked to try to select the highest functioning level modes of automation (i.e., giving the most guidance). During the training phase, pilots in a non-exploratory (control) group were told about these failures and corresponding solutions in advance, whereas the pilots in an exploratory group had to figure out the solutions by themselves. Both groups were told the correct solutions after each exercise. In a subsequent test containing new, surprising failures, the exploratory group was significantly quicker in finding the solutions. This suggests that proper frames can best be built through exploration and problem-solving, and that such training may benefit pilots when they encounter surprising situations.

Self-management of Surprise

To see whether awareness of reframing helps, and self-management of surprise is possible, we investigated the effectiveness of a checklist-based method (Landman, et al., 2020). This method is inspired by the unofficial 'resetting the clock' procedure, which was previously used by US Navy pilots (Croucher, 2008). This quick, goal-directed action was meant to prevent hasty responses and induce a sense of control. Thinking along similar lines, we

Figure 3. The Simona research simulator at Delft University of Technology.

hypothesised that a simple memory-item checklist can provide pilots with a tool to 'recover' their brain during surprise.

In our study, we trained pilots to use a four-item checklist, COOL: Calm down, Observe, Outline, Lead. We found that pilots liked the method, remembered to apply it in surprising situations, and showed better decision-making in some situations when compared to pilots who were not trained with this method. However, it also induced some counterproductive workload, and sometimes seemed to interfere with the prioritisation of issues that should take precedence over the COOL checklist.

"A brain recovery method should at least include an item of stress management as well as an item of observing the general situation to collect information and prevent hasty response."

Based on the pilots' feedback, we concluded that a brain recovery method should at least include an item of stress management (e.g., by taking a deep breath, such as 'tactical breathing' as it is called in the military), as well as an item of observing the general situation to collect information and prevent hasty responses. We are currently investigating an adapted checklist (ABC – Aviate, Breathe, Check), which is shorter and should help pilots prioritise their actions better.

Conclusion

The key problem with surprising events in stressful situations is that under stress the brain cannot access (or is unaware of) the appropriate mental frame needed to make sense of the situation. Our research has shown that training interventions, such as adding variability, unpredictability and exploratory training can improve one's sensemaking skills. In addition, we showed that a simple memory-item procedure, which includes an item of stress management, can help pilots to cope with surprising events and prioritise their responses. We are currently applying our knowledge, for instance, to investigate the effect of surprises caused by spatial disorientation, and to identify inadvertently counterproductive ways of training for surprising events (i.e., negative transfer of training). S

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Prof. Max Mulder, PhD, is full professor 'aerospace human-machine systems' at the faculty of Aerospace Engineering, Delft University of Technology. He leads the section 'Control and Simulation' which investigates reaching higher levels of automation in aviation.

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