ON BEING PREPARED TO BE SURPRISED:
20 KEY INSIGHTS FROM DAVID WOODS

Over the last four decades, **Professor David Woods** has studied and advised government agencies, companies and accident investigation boards on surprises and unexpected events in industries including aviation, space exploration, healthcare, and software engineering. **Steven Shorrock** picks out 20 key insights from a conversation on being prepared to be surprised.

1. The process of surprise follows a familiar pattern

"Beginning with an initial signal, the process flows across a series of transitions from a physiological response, to a sensory response, to a more interpretive perceptual response, and an emotional response, to a more cognitive then cooperative activity. The whole transition needs to go smoothly and coherently across those stages. At some point we realise, '*This doesn't fit!*' This marks the transition to a sense of surprise: '*I'm in a different world. I am now in abnormal operations. There are unexpected, anomalous, and discordant indications to resolve.*' People can get thrown into a kind of incoherence along the way. You're thrown off track and it's hard to get back on track given the time pressure. That's when the response breaks down."

2. We confound surprise, the unexpected, and startle

"In the flight deck, the word 'startle' sometimes gets misused. Startle refers to a physiological response to threatening, sharp onset signals – a sudden dramatic shift. Startle delays response and can disrupt initial processes to monitor or scan, recognise, understand the event and what it means for response. But mitigating that is difficult. Startle is controllable in a very limited sense and in terms of very specific kinds of things, which

don't work for everybody. There are significant individual differences."

3. Surprises can be situational or fundamental

"Surprise is about the unexpected. Surprises challenge our model of how the world works or should work. When surprised, we have to make sense of what doesn't fit. This can take the form of a situational surprise – how to minimise the implications of the surprise (just a little fine-tuning to restore the model). Alternatively, the response can take the form of a fundamental surprise where people engage in processes of revision and re-conceptualisation."

4. The only certainty is uncertainty

"Sometimes, the only thing I know for sure is that there's high uncertainty. But this can be a definite signal telling me I have to get more information, and I have to create the possibility for swift action once I understand what's going on. The big question is, are you prepared to revise as more evidence comes in? You may have to back up and re-examine what's really going on in terms of what you can see and hear and feel. This is where the classic questions arise during automation surprises: '*What's it doing? Why is it doing that? What is it going to do next?*'"

5. The transition to scan after surprise is critical

"It is important to help support people to get back into a disciplined scan in the computerised cockpit. In the old analogue cockpit, experienced pilots had a very disciplined scan to make sure they were getting all the information relevant to understanding a potentially abnormal situation."

6. Simulator responses can be very different to real world responses

"Even though it's full scope and high fidelity, pilots know they're in a simulator, and the ability to respond to an abnormal situation is always faster than in the real world. So, you should always design and train with that in mind. It's a different world and a different tempo in the air. A five to 10-second response in the simulator might even double in the real world."

7. Therapeutic responses give crucial diagnostic information

"Actions can help you figure out what's going on (the unexpected part), while potentially helping to handle the situation (the abnormal part). You don't have to know immediately why the engine is losing power, but you do need to stabilise flight as power drops. The actions to respond are corrective, or therapeutic, as they help manage the situation. The very same actions also provide diagnostic feedback. How the aircraft and systems respond to actions reveals more about what is wrong and what does or does not explain the situation. Plus, what produces the surprise can lead to unexpected actions by automated systems. Tracking what the automation is doing or not doing can get difficult under time pressure. The classic view of a strict linear sequence from assessing information, building a diagnosis, then acting, doesn't capture how these are intertwined during surprise events."

8. Sudden collapse can happen at the system level

"In socio-technical systems, the processes that respond to surprise and coordinate responses across subsystems can degrade. We normally compensate, but we can run out of the capacity to continue to handle a growing problem or a deteriorating situation. As things get worse, the ability to continue to respond diminishes, leading to a sudden collapse in performance. In control systems this is the general problem of saturation. It is also how brittle systems fail. In trying to keep up with threats, the system needs the capacity to stretch and adapt to handle the effects of surprise and reduce the risk of brittleness. This is a special capability that experienced expert people provide."

9. The way that we think about probability misleads us

"Classically, people think of surprise in a probability sense. Surprising events are relatively rare events, in the tails of the distribution. The problem is, in real world probability distributions, the tails are bigger than we think. In other words, the probability of low frequency events as a class is much higher. It's not that surprise is rare. Surprise is always happening at the boundaries. After the Columbia accident, I said to Congress that, paradoxically, extra investment in safety is most needed when it's least affordable. You need to be prepared to be surprised and prepared to adapt."

10. It is necessary to focus on reliability, robustness and resilience

"You have to prepare for all three because they're so different. You can't know all of the things that will go wrong, and you don't have enough resources to prepare for all contingencies. Plus, the world will change. We rely on the pilot to understand and act constructively in a situation that doesn't fit what we thought we were prepared to handle."

11. Everything operates under limits

"It's not that designers are bad at their jobs. It's that everything operates under limits. Engineering design operates under limits. The machines that result have limits. People operate under limits.

And the world keeps changing. Those changes will present surprises that highlight the limits of our decisions. What reasonable trade-offs will need to be readjusted as we appreciate the new information in surprise events? This was missing in the run up to the Columbia accident."

12. The act of compensating successfully hides what is difficult

"There is a law called known as the fluency law. It means you adapt successfully most of the time. As a result, you and others don't see the difficulty, or the trade-offs, or the dilemmas that arise, but are handled regularly. There is a source of strength in people that is hard to appreciate even though it is called into action regularly to handle the stream of small surprises in all systems with limits. Often, no one noticed that they were adapting to recover, demonstrating resilient performance. And we didn't notice that because people – in the end – handled it successfully, leaving the surprise and adaptation partially invisible."

13. We have to be prepared to be surprised, even by our own mitigations

"So, when we say, *'how to be prepared to be surprised?'*, we mean that your model of the world does not match the world you're really in. What we thought of as risk mitigation shifted trade-offs and exposed us to other risks. So rather than always getting better and the probability of something bad happening always going down, vulnerabilities actually change. We are more effective in some ways, but the system changes and we get surprises."

14. Adaptive capacity is future-oriented

"We have to think about adaptive capacity as a potential to act in the future when things are different than planned. We know that we have finite resources, and we have to make compromises and trade-offs even as we pursue reliability and robustness. We know that challenges will arise, but the challenges will arrive in unfamiliar forms. Things work as well as they do because there are hidden sources of resilient performance to handle the regular occurrence of surprising events."

15. We need to understand how people handle surprises

"To some degree, we start to reveal fluency by getting people to share more information about how they do things. What makes you as an experienced controller different from a newer controller? If you're supervising a relatively inexperienced person, what do you bring to handling a situation that's different? As you recognise that a situation may become more difficult to handle, how do you make small adjustments in advance?"

16. People provide the ability to stretch

"Management must first understand that people adapt to handle surprises and other difficult situations. People

provide an ability to stretch at the boundaries. It doesn't have to be people, but it turns out it is almost always people. Pilots, controllers, engineers and other actors provide a source of resilient performance; they adapt to make the system work. And we count on that."

17. Experience matters

"It is important to appreciate that there's great value in experience. This requires long-term planning to retain this critical asset for resilient performance. You need a balanced portfolio with a long-term approach to sustain the base and mix of experience."

18. You can't take past safe performance for granted

"In ultra-safe systems, there is a risk of taking past safe performance for granted. But again, a record of reliability does not guarantee future robustness or resilient performance. If you rely on a record of past reliability, you'll have less robustness than you think, and you'll cut out some of the critical human sources of resilient performance that help you handle surprises and other difficult situations."

19. The world will throw more surprises at us

"Today the world is going through transitions and changes that reverberate in unusual ways or ways that we don't expect. The world will continue to change in ways that will be surprising in terms of their tempo and impact."

20. Managers need to be agile

"By the time you put in your traditional change programme, the world has moved on twice! You need to be more highly adaptive in a turbulent world and that requires management to rethink things. In the new world we're living in, management has to learn to be agile. Management cannot be slow and stale. You must develop the potential to adapt in a changing world."

Read the full interview with David Woods in the Online Supplement to HindSight 34 on SKYbrary at https://skybrary.aero/articles/hindsight-34

Professor David Woods has worked to improve systems safety in high-risk complex settings for 40 years. These include studies of human coordination with automated and intelligent systems and accident investigations in aviation, nuclear power, critical care medicine, crisis response, military operations, and space operations. The results of this work on how complex human-machine systems succeed and sometimes fail has been cited over 33,000 times and synthesised in several books. He is Past-President of the Human Factors and Ergonomics Society and the Resilience Engineering Association. He has received several awards and has provided advice to many US and international government agencies, companies, research councils, task forces, and accident investigation boards.