UNDER PRESSURE

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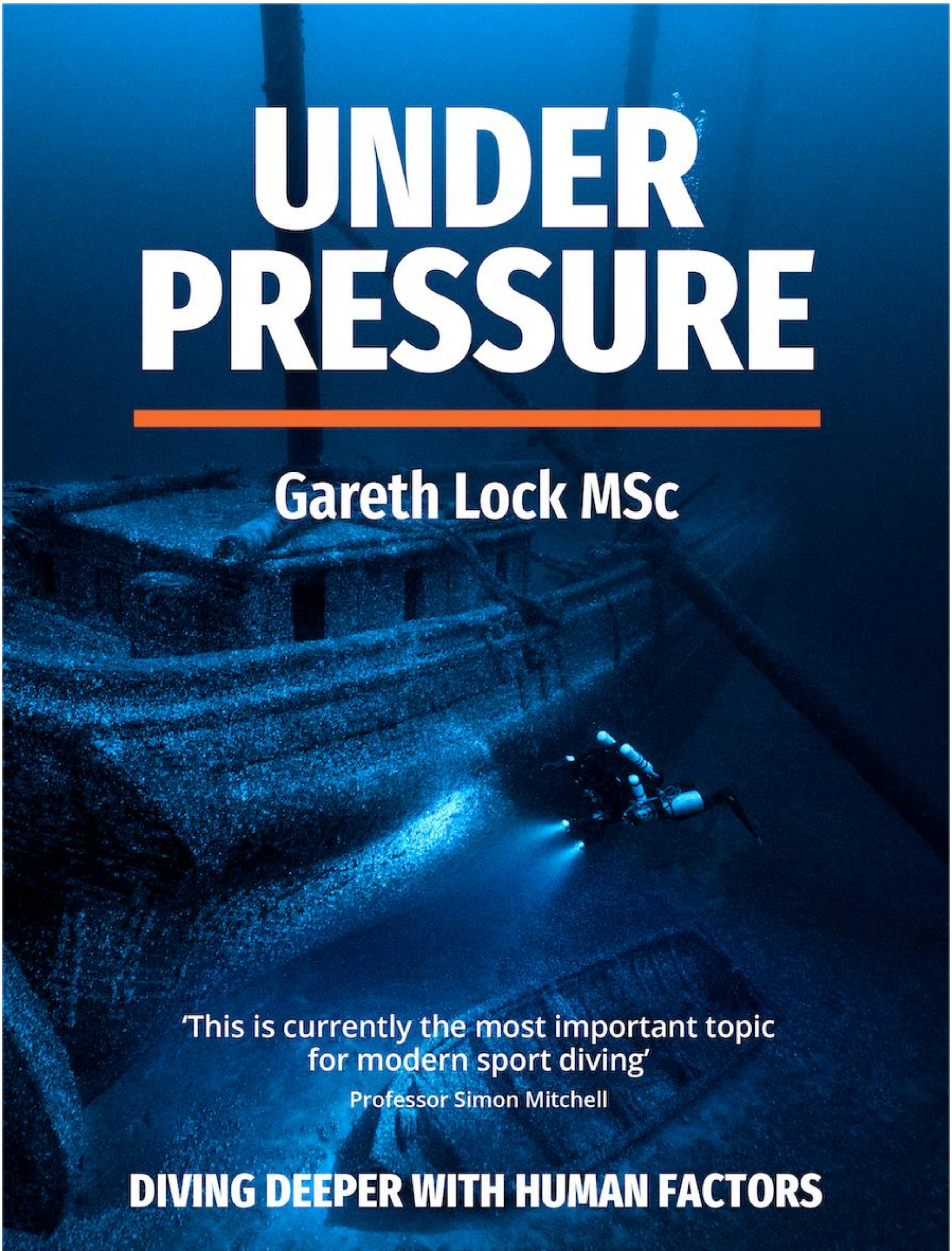
'This is currently the most important topic for modern sport diving'

Professor Simon Mitchell

DIVING DEEPER WITH HUMAN FACTORS



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Introduction

This eBook provides a brief introduction to the topic of non-technical skills and human factors in diving, and a greater insight into decision-making in diving. The case studies provided show how it is quite easy to miss critical information when stresses are high, or when goals are clouding our judgements. However, this is easy to see in hindsight and we must remember this whenever we read an account written after an incident or adverse event. Divers, in the main, don't get up in the morning and decide, 'Today is a good day to make a monumental cock-up that could cost me, my buddy or my student's life'. Whatever they have done makes sense, and if we are to improve diving safety, we need to understand that local rationality. The eBook covers three of the chapters from the paperback book of the same title which will be released in March 2019.

The application of non-technical skills and human factors to diving will improve both the performance of divers so they can achieve more and (crucially) have more fun, and as a by-product of improved performance, the divers will be safer. However, the biggest hurdle to including human factors and non-technical skills in your own practices is the need to really recognise that we are all fallible, not just other divers. As Atul Gawande highlighted, more than 90% of surgeons, if they were going to be patients in a surgical theatre, would want their surgical team to use a checklist, but only 20% of them actually use one themselves! Is that because they think other surgeons aren't as good as they are?

The eBook and book are based around the globally-unique programmes I have put together which take the knowledge, skills and attitudes regarding human factors and non-technical skills from high-risk industries and frame them in the context of recreational, technical, cave and rebreather diving. The materials are also suitable for those involved in public-safety, scientific diving, commercial and military diving.

The main book has been written in a format which allows the readers to dip in and out of each section to gain essential knowledge, but the greatest effect will be to read the book from start to finish. There is a good reason for this - these skills are interdependent and for maximum effect need to be executed in a psychologically-safe environment. For example, developing your leadership skills without understanding the effect of the biases which impact your followers' decision-making, will reduce your effectiveness as a leader. As you progress through the book and learn more about the skills, you will realise the true interdependence of non-technical skills.

Each chapter follows the same format - a relatively detailed case study highlighting a success or failure, followed by human factors and non-technical skills theory interspersed with examples from diving, then another case study to demonstrate the key points, and finally each chapter will close with a section with key practical advice for the reader to apply the skills to develop themselves and their teams to be high-performing. References are also provided at the end of each chapter for those who want to dig deeper.

In the same way that art schools cannot provide you with a 'proven method to create stunning art' this book will not provide you with a 'proven method to improve your diving', rather it will give you the self-awareness and adaptability to apply the skills in an interdependent manner, understanding the strengths and weaknesses of human performance in an ambiguous and uncertain world. There is no one right answer about how to solve problems, other than maybe learning from yours and others' failures along the way. Unfortunately, while there is no shortcut to life, we can accelerate the learning process by learning from those who have made mistakes, who have identified the lessons they learned and then abstracting them to our own domains and applying them, and finally ensuring that our own feedback systems are in place so we can learn from our mistakes when they happen.

Chapter 1 - The Role of Human Factors and Non-Technical Skills in High-Performing Teams

"Accidents are complex processes involving the entire socio-technical system. Traditional event-chain models cannot describe this process adequately."
Professor Nancy Leveson, 'Engineering A Safer World'

In 2009, the Airbus A320 took off from New York's LaGuardia Airport laden with 150 passengers and 5 crew, en route to Charlotte Douglas. At an altitude of height of 2818 feet, and just 135 seconds after the wheels left the tarmac, the Airbus flew through a flock of Canadian geese. A loud bang was heard, and both engines suffered an immediate loss of power. Alarms started to sound in the cockpit with flashing warning lights signalling to the crew that there was a problem which needed their immediate attention. The noise from the alarms, the vibration from the airframe and the visual stimuli from the captions and displays, all required processing to ensure that important and relevant information was not lost.

The Airbus, as with all modern passenger jets, had been designed to operate with one engine failed at the most critical stage of flight without a loss of altitude. However, the crew were now faced with potentially two engines failed as they did not have a clear indication as to what was happening, although they knew that they had lost power. They were having to deal with ambiguous information and make the best decision they could, given the limited information they had.

At the most basic level, while there is a procedure for a double-engine failure in a two-engine aircraft it is only applicable when the aircraft is at high altitude. Altitude was not a luxury the crew had, and time was of the essence. The crew started to work through the checklists. Twenty-two seconds after the bird strike, Sullenberger transmitted on the radio, "Mayday, Mayday, Mayday, this is Cactus 1539 (correct call sign was Cactus 1549), hit birds. We've lost thrust on both engines. We're turning back towards LaGuardia..." to ensure that Air Traffic Control (ATC) were aware of the situation and that they could start their own emergency procedures which would include clearing airspace. This transmission would have also been heard by other aircraft crew who would now know not to transmit unless there was anything equally urgent. The training previously undertaken by aircrew and Air Traffic Control (ATC) meant that each of this diverse team knew what would likely happen next - they shared a common situation awareness model.

The problem with checklists is that sometimes they don't align with the situations being encountered by the crew and so the operators have to adapt. In some environments, deviation from procedures is met with negative criticism because there is an assumption that they must be followed at all costs, even if this leads to a wrong outcome. For the crew of CACTUS 1549, there was no checklist for double engine failure at low altitude, so they were in definite adaptation territory, a point picked up in the National Transport and Safety Board (NTSB) accident investigation. However, the Captain knew that they would need some form of electrical power generation to power the aircraft systems and so turned on the Auxiliary Power Unit, a small 'engine' which would generate enough electrical power to power the radios, flight control systems and other emergency equipment. This was a deviation from the standard operating procedure (SOP) because the emergency checklist had this action as step number 11 in the 15-item list of actions. This was a deviation that was needed because the situation dictated it and they understood the rationale behind the checklist design.

Thirty-five seconds after the massive bird strike which had reduced the thrust from the engines to almost zero, and after they had mentally run simulations with potential outcomes, they turned back towards LaGuardia airfield which was 8.5 miles away. All the time the clock was ticking, the aircraft was descending, and the ground was getting closer. Shortly afterwards, Captain Sullenberger informed his crew and Air Traffic Control that he was going to be ditching into the Hudson River, the only place he could see which was long enough and clear enough to put the aircraft down in this densely populated area and have any chance of survival. However, I am sure that he was aware that the survival in such circumstances was slim despite it being a regular scenario covered in training simulations, but this was the best possible hand to play in a terrible game. Once that decision was made, the execution of the ditching drills took place with professionalism and calm.

At 3:11pm, 360 seconds after take-off, 229 seconds after the bird strike, and 90 seconds after the Mayday call, Flight 1549 touched down onto the surface of the icy, cold Hudson River in a level trajectory at 140 mph (230 km/h). The aircraft came to a rest and remained floating on the surface with no fatalities and only a few minor injuries caused by the massive deceleration which caused legs and arms to flail. The aircraft remained relatively intact and upright.

The crew executed the emergency evacuation drill using the over-wing doors. The evacuation slides were deployed and became life-rafts, as they were designed to do. One passenger panicked and opened the rear door which was unable to be resealed and led to the cabin filling with water from the rear. In addition, water was coming through the cargo doors and the fuselage. The captain was the last to leave the aircraft having walked through the cabin twice, through the 5C water, to ensure there was no-one left behind. Fortunately, due to where they had landed, there were already a number of boats and passenger ferries already congregating on the scene to help people from the life-rafts to safety. The last person was recovered from the aircraft 44 mins after the touchdown.

There is no doubt that this event was only possible through the high level of technical skill i.e. piloting of Captain Sullenberger, his First Officer and cabin crew. However, having technical skills is not enough to be a high-performing team. They needed non-technical skills, crew resource management skills or ‘soft skills’. These include:

- situational awareness to determine what was most relevant at the time and focus on that, excluding 'irrelevant' information.
- effective decision-making skills to sift through the masses of data coming from their eyes, ears and tactile feedback systems and then determine the best possible decision with the information they had there and then.
- effective communication skills to share their knowledge and decision-making processes so that a shared mental model was available to others within the team.
- strong and stable leadership which imparted role clarity and confidence to ensure the actions which needed to be executed in a timely manner were clearly understood.
- strong followers who listened, challenged when needed and trusted their captain to make the right decision, and working towards a common goal; a clear sign of effective teamwork.
- the recognition that stress would limit their cognitive skills and so remained as calm as possible despite the dire situation they were in. The calm was a result of the

realistic training in simulators and the detailed debriefs which crews undertake to learn from the continual failures and errors made.

However, these non-technical skills did not just pertain to the execution of their technical skills using the team inside the aircraft, they also applied to those supporting organisations and wider team members outside the aircraft. These include Air Traffic Control, the emergency services and other aircraft in the vicinity of the emergency.

Aviation is considered one of the pinnacles of excellence when it comes to human factors and non-technical skills training and application. The consequences of errors and violations are massive which is why organisations spend so much time, money and effort in reducing the likelihood of accidents and incidents by focusing on the human within the system.

The behaviours, traits and actions of divers are no different than pilots, air traffic controllers and maintenance teams when it comes to human performance. Some of you could argue that civil and military aviation operations have a regulator who states they have to have such training systems in place. However, most organisations would keep human factors and non-technical skills programmes because it makes sense to do so as they lead to improved performance and safety, which comes as a by-product of that high performance.

Technical Skills versus Non-Technical Skills

What are non-technical skills? To understand non-technical skills, let’s look at what technical skills are. In the context of a pilot, their technical skills are related to flying the aircraft, moving the flying controls and throttles to keep the aircraft on its planned trajectory. In a surgical environment, a surgeon can incise and suture. On a drilling platform, the driller will control the speed and pressure of the drill to progress down the hole. These are all technical skills to achieve their requisite goal. Their non-technical skills relate to being able to perceive, process and apply the relevant information, make effective decisions based on that information, to communicate to the rest of the team to ensure they have a shared mental model, as well as execute commands as needed, to recognise the effects of stress and fatigue on their team and maintain stressors for optimal performance. These don’t directly relate to the goal at hand, but without non-technical skills, you can’t get very far. In high-risk domains, without effective non-technical skills, accidents happen like the collision of two Boeing 747 aircraft in Tenerife in 1977 which lead to the loss of 583 people when a loss of situational awareness and miscommunication occurred, or the loss of the Deep Water Horizon platform in the Gulf of Mexico when the drilling crew had made assumptions about what was going on in the hole, to a news story in the national press, of a surgeon who removed the wrong kidney while being watched by a student nurse who recognised the problem, spoke up but was ignored by the surgeon.

In diving, things are a little more complicated because we have the terms ‘recreational diving’ and ‘technical diving’ which are used regularly, but there isn’t a clear definition of what the latter means as each agency applies different metrics.

Do non-technical skills mean recreational skills? No. In the context of human factors and human performance in diving, which is what this book is all about, technical skills relate to the use of buoyancy control devices, putting up a deployed surface marker buoy (dSMB) laying a line in a cave or wreck and using video/photography equipment to create lasting memories, or similar activities. Non-technical skills relate to communicating the plan for a photo shoot, the awareness when laying the line that it doesn’t get caught in a trap which would prevent a blind-exit, or the decision to end a dive as the current has picked up and staying to the planned bottom time would mean that gas reserves would be insufficient.

In normal operations, non-technical skills have significant benefits because they help everyone ‘sing from the same song sheet’, but in situations where irregularities are present e.g. when the plan deviates or there is an emergency, then non-technical skills really come to the fore. If there are no surprises, there won’t be any accidents and non-technical skills help reduce the number of surprises we have.

The Application of Non-Technical Skills in Diving

This sounds a lot like common sense, so how do these non-technical skills apply to diving? The following brief case studies highlight where the application of non-technical skills was insufficient.

Open Circuit Recreational

An Advanced Open Water (AOW) diver with around 50 dives was acting as an ‘assistant’ to the instructor and dive-centre owner on a guided dive with five Open Water (OW) divers and recent graduates from the school they themselves had learned at. The AOW diver felt a social obligation to help the Open Water Scuba Instructor (OWSI) who was leading the dive because the OWSI had done so much to help her conquer her fear of mask clearing during her own training. However, she was also wary that over time her role had moved from being a diver on the trip to being almost the divemaster by helping other divers out which she wasn't trained to do. In addition, the instructor regularly asked her, at the last minute, to help out and change teams to ensure the 'experience' dives happened.

On this particular occasion, the AOW diver was buddied with a low-skilled OW diver who was arrogant and did not communicate well. In fact, she didn't believe that 3 of the 5 on this trip should have received their OW certificates given their poor in-water skills. As they approached the dive site, the visibility could be seen to be poor from the boat and the surface conditions weren't great. The instructor said to the AOW diver, "Don't lose the divers. I want you at the back shepherding them."

They entered the water and descended to 24m and made their way in the poor visibility. On two occasions the OW buddy had to be brought back down by the AOW diver as they ascended out of control. At one point, the OW diver turned around really quickly and knocked the AOW diver into the reef. Unfortunately, the AOW diver became entangled in some line there and the OW diver swam off, oblivious to the entanglement. When the 5 divers and instructor reached the shotline ready to ascend, the instructor realised the AOW diver was missing. They couldn't trust the five divers to ascend on their own and didn't have enough time to wait at the bottom and conduct a search, so the six ascended. On the surface the buddied OW diver said that the AOW diver had swum off looking at fish in a certain area.

In the meantime, the AOW diver had managed to free themselves, but in their panic, while stuck on the bottom, they breathed their gas down to almost zero and had to do a rapid ascent. They surfaced, feeling very scared and sick with panic, just as the instructor was speaking to the other six on the surface. On seeing the AOW diver break the surface, the instructor swam over and shouted at them for abandoning their buddy on the bottom. The AOW diver felt very alone and wanted to give up diving as she was not given the opportunity to tell her side of the story.

Contributory factors

- Violation for personal gain on the part of the instructor/dive-centre owner taking OW divers to 24m.
- Authority gradient between the instructor and AOW diver meant that the AOW diver felt they couldn't end the dive before they even got in the water or once in the water.
- Inferred peer pressure to help out when they weren't qualified or experienced enough to act in a supervisory role.
- Poor technical skills on the part of the OW divers and the AOW limited their capacity to be aware of hazards and risks.
- Limited awareness on the part of the instructor regarding the location of all of the divers during the dive.
- Positive note - good decision on the part of the instructor to ascend with the five OW divers in poor conditions and not keep them on the bottom or get them to ascend on their own.

Open Circuit Technical

Two divers descended a shot-line in very poor visibility to a depth of 45m while breathing weak Nitrox. As they descended, one of the primary torches failed and the team swapped position so the diver with the brightest torch was in front. On reaching the bottom, they started to move around the huge wreck with the hull on their right. Shortly afterwards, the hull 'disappeared' and they both thought they had swum off the wreck. They turned right to find the wreck and after a little while they realised they were inside the wreck at a dead-end with no line laid to get back out.

Both divers panicked, one of them losing their mask in the process. The diver who lost his mask took out his spare and managed to find his way back out but did not see his buddy while doing this. While still stressed and breathing heavily, he used a spool to go back into the section of the wreck he had just come from to look for his buddy. After a few minutes he realised he wasn't there as he reached the same dead-end they had previously been to. With the fear of telling his buddy's wife of his death playing on his mind, he ascended and completed his 30mins of decompression.

On surfacing he found that his buddy had made his way out and had made a straight ascent to the surface as he had almost no deco to complete. Both divers had a precautionary recompression chamber run that evening.

Contributory factors

- No contingency plan, failure wasn't expected. Neither had dived in visibility so poor before and neither had a reel for lining off.
- Time/money/social pressures to complete the dive. Both divers had travelled two days to get to the dive site and be able to dive this wreck as part of a week long live-aboard trip and didn't want to lose out on a dive.
- Equipment reliability and test. The torch had only just been serviced after a fault and had not been tested to make sure the fault had been fixed. The divers on losing a primary light in poor visibility decided to carry on despite the poor (1-2m visibility).
- Nitrogen and carbon dioxide narcosis clouded the divers' decision-making abilities.
- Expectation bias that the hull disappearing meant that they had swum off the wreck and not that a massive hole in the hull was present.
- Reduced awareness due to narcosis and visibility to the extent that they did not notice they were swimming into the wreck until they reached the end of the section and hit metal, above and to the sides.
- Excessive levels of distress caused by uncertainty and narcosis.

Closed Circuit

Two experienced OC Trimix divers, one of whom was an OWSI, were undertaking an Air Diluent Closed Circuit Rebreather (CCR) class at an inland dive site. After the first dive of the last day had been completed and lunch finished, the class returned to the dive entry point to start their final dive of the day. However, on checking gas pressures, one of the students realised that their diluent cylinder only had 70 bar (approximately 1000psi) in it. This was not enough to complete the dive, so they took the cylinder off and rushed up to the gas station to get an air top. They paid for it, not noticing a higher price than normal (as they had been out of diving for some time) and returned to the entry point, now realising that time was getting on to complete the dive before the centre closed. After putting the diluent cylinder back on, they got ready to dive.

All three entered the water and started their descent down the shotline. As they descended, the subject started to get a high pO2 alarm on their Head Up Display (HUD). They added diluent to their loop, but the alarm remained. As they reached the bottom of the shot at 18m, the student signalled to the instructor that something wasn't right, but the instructor swam off not acknowledging the communication. The student bailed out and the noise of the open circuit regulator brought the instructor back. The student again signalled that something wasn't right. The instructor flushed diluent through the loop and the pO2 was still high. At 18m the pO2 should have been 0.6 but it was reading 2.0. The instructor signalled for everyone to ascend.

On surfacing and analysing the gas, the diluent cylinder was found to contain 72% O2. The 'air top' had in fact been an 'O2 top' on top of 70 bar of air. The gas hadn't been analysed by the diver or the fill station prior to it being connected to the rebreather.

Contributory factors

- Despite the course standards saying so, the instructor and students never analysed their gas all week. This series of violations was set in motion by the instructor role- modelling poor behaviour on day one.
- Time pressures, given the last dive of the day & course and that the refilling station was close enough to get a fill and still complete the class, but far enough away which required rushing to complete the pre-dive sequence.
- Incomplete pre-dive sequence and pre-breathing process carried out prior to the dive. A full diluent flush was not required as part of the checklist, only operation of the Manual Add Valves, but a full flush and test of the controller would have picked up that the diluent gas was not air.
- Poor confirmation on the communication at the bottom of the shotline when the instructor swam off.

- Not noticing at the end of the first dive that 70 bar would be inadequate for the second dive and getting the fill done over the lunchtime period thereby reducing the time pressures and subsequent stress.
- Social pressure to conform and get in the water as quickly as possible.

Each one of these diving case studies has multiple non-technical skills deficiencies and yet the topic of non-technical skills is not covered in much detail in diver and instructor training - this book and the training programmes which are produced and supplied by *The Human Diver* aim to address that shortfall.

The application of non-technical skills increases fun and improves safety

The following shows what happens when effective non-technical skills do come to the fore.

Six divers had decided to undertake a 30m dive from an RHIB. John and Dave were diving as a team with their local university dive club and had over 2000 dives between them. Graham was relatively newly trained as a marshal (surface manager) and had not worked with Brian before. On the dive boat, there were two new divers to the club, Gail and Mark. Both Gail and Mark had successfully completed a check-out dive & dry suit familiarisation course with another instructor in the club, and they were already certified for 40m diving. Graham was keen to do a drift dive in 32m of water. Brian, the cox, was somewhat worried about the conditions as there seemed to be waves forming. However, as long as all divers were certified to 30m diving and effective at getting into the water and back onto the RHIB, he was happy that the risk was acceptable. To allow the cox and marshal to dive, John and Dave would take over in the coxswain and marshal roles after the first dive.

At the dive site, there was a small swell, no white horses, but it was not possible to prevent an uncomfortable rolling of the dive boat. As Diver A was starting to prepare his equipment, he observed Gail and Mark who appeared to be very apprehensive and struggled to perform simple tasks as part of their buddy check. Low Pressure (LP) hoses were not connected, SPG's were not clipped off and there seemed to be a lot of effort used on simple tasks like putting drysuit and gloves on. Furthermore, both appeared to be physically shaking and very pale. John asked the dive marshal if he had noticed the apparent stress building with Gail and Mark. He had not because he was focused on getting his own dive kit ready for his dive. John suggested to the dive marshal to ask them if they would prefer to dive the sheltered bay with a maximum depth of 10m, quietly reminding him that it was their duty of care to stop diving operations if he believed that the conditions or behaviour of the divers were not safe.

At this point, Graham picked up on the cues and, in a calm and professional manner, sat with the anxious divers to discuss the diving plan. It was then established that Gail and Mark would very much like to do the shallower dive, because apart from the club drysuit course, it came to light that they had never dived in drysuits before, from a dive boat, in high flow or in water deeper than 20m before. While they were certified for the depths and drysuit, they had become extremely stressed as they had thought the dive would be a maximum of 20m on a wall, rather than 32m flat bottom in extreme spring tides in much faster and colder water than they were used too. They had not wanted to “make a fuss" by telling the more experienced divers on the boat that they were concerned.

The dive plan was changed, and the boat was moved to a very sheltered bay with perfect conditions and no tidal movement. After they arrived at the new location, Gail and Mark relaxed and on restarting their briefing and checks, they quickly and calmly fixed the small issues observed during their first aborted dive. They used the dive both to enjoy the kelp forest at 10m, but also to practice their ascents and using a dSMB in cold water.

In their de-brief they concluded that they needed to do lots more shallow dives to get used to the new cold water conditions, and that they would prefer, in the future, to be paired with club members with more experience until they felt more comfortable in the water, and they set their own depth limit to 15m until they felt more comfortable with drysuit ascents.

Contributory factors

There were a number of factors which worked against Gail and Mark and these will be covered in more detail during the book. However, the reason for detailing this story is to show how non-technical skills can be used to improve performance and prevent incidents from happening.

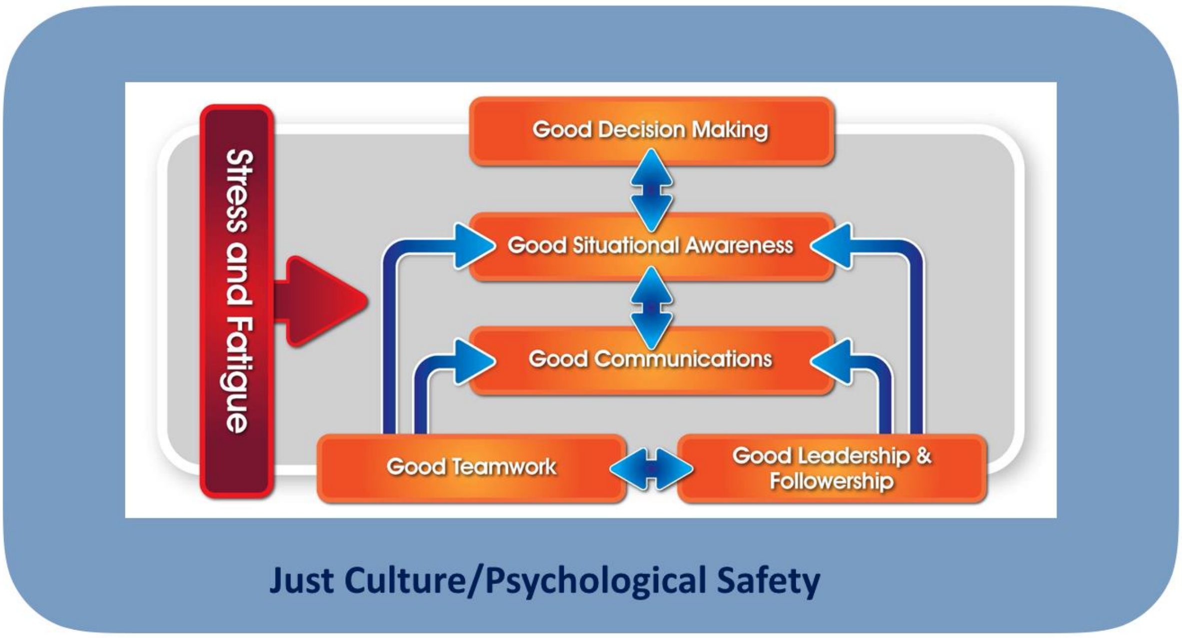
- Situational awareness to notice that Gail and Mark were apprehensive and that their behaviour was not normal.

- Assertion skills to reinforce to the dive marshal that events were not likely to go to plan given the mental state of Gail and Mark. Despite the marshal (Graham) being present and observing the same scene as John, he did not have the same mental model which John did because of his previous experience.
- Leadership skills on the part of the dive marshal in communicating with Gail and Mark to ascertain their issues with a view to resolving them.
- Debrief leading to effective decision-making for the future by Gail and Mark to limit their diving exposure until more experienced.

The Interdependence of Non-Technical Skills

Over the years, diver training organisations and clubs have developed in-water 'technical skills' for their divers, instructors and instructor trainers to maximise safety and enjoyment. In addition, equipment manufacturers have developed and adopted standards which increase the reliability and performance of equipment making diving safer. However, very few (if any) of the training sessions provided by training agencies focus on the 'soft skills' or non-technical skills required to make effective decisions in dynamic and uncertain environments, especially when operating in a team environment.

Model of Non-Technical Skills and their Interdependence



The above model is a simple framework I have created for my own teaching to explain the linkages and interdependence of the non-technical skills. It has decision-making at the very top, as ultimately this is what we want to achieve as part of any process. Feeding into decision-making is situational awareness, where we perceive, process and project this information into a future state. To gain relevant situational awareness, we need effective communications between our team members and any technical systems we use such as dive computers or rebreather controllers. To support this we need effective teamwork, robust leadership and trusting followers. However, all of these skills can be negatively impacted by stress and fatigue degrading any positive benefits gained. We also need to have a psychologically-safe environment and a *Just Culture* present so that failure does not have a stigma associated with it. This safe environment is essential because it allows learning from failure to occur, recognised as the most effective way of creating improvement which will have long-lasting value.

Understanding 'the System'

If we are to improve performance of people and organisation, we must understand the concept of a system and how to improve that and not just the components. We can certainly improve decision-making with applications, software and flow-diagrams to gather more data and crunch the numbers, or communications by having team training sessions and profiles undertaken, but without understanding the interactions within the system, we might only make minor improvements or, worse still, we crash the system and nothing works. Chapter 2 will provide an overview of systems thinking and how it contributes to a changed view on human performance and safety. Without such a revised view, improvements will have limited impact on safety.

Chapter 3 - Human Error. A terrible term to apply if we want to learn from what happened!

"*'Human error' after all, is no more than a label. It is a judgment. It is an attribution that we make, after the fact, about the behaviour of other people, or about our own.*"
Sidney Dekker, 3rd Edition Field Guide to Understanding 'Human Error'

Case Study: Losing the plot!

Tim Clements describes a task where he and his partner had to retrieve twelve hydrophones from twelve different shotline locations in an array with depths varying from 3 to 24m and due to some cognitive failures, things didn't go quite to plan.

The total path to be travelled was 1.3km and the dive team chose to use both CCR and DPV to optimise breathing gas and travel time. The dive was a repeat of previous dives to recover, download the recorded data and to redeploy the hydrophones - the task was familiar and had been previously completed without incident or complication.

During the dive my mask leaked. A small, but niggly thing, distracting me and requiring frequent clearing. This makes CCR buoyancy control more difficult, especially in shallow water, as gas used to clear the mask must be replaced from the diluent bottle, which in turn requires the addition of O2 to make the desired nitrox in the loop. Any extra gas and the diver rises, the PO2 drops and the CCR injects again.

On the deeper transits, this wasn't too much of an issue. The navigation suffered a little from distraction, requiring an adjustment, but the deep hydrophones were retrieved and stored in a mesh bag towed on the right-hand side, balancing the bailout bottle on the left-hand side.

In the shallows, the distraction and frustration increased. I was becoming increasingly aware of buoyancy changes from gas injection while in the shallow water and could not get settled into a stable DPV towing position. The towed bag on the right was lying over my backup display and torch clips and this was causing issues with dive performance and comfort levels. With three hydrophones remaining, at positions #3, #2 and #1, I decided to stop and reset. Clipping the bag and DPV to shot #3, I untangled the torch and backup display cables, got everything how I like it again and felt much better. That is, apart from the mask, which still leaked. Hydrophone #3 was *cut free, put in the bag and the shears stored in their belt pouch. We scootered to shot #2. Leaving shot #2, I knew we only had one to go, about 10m away around a corner. Hydrophone #1 was retrieved, and we scootered along to investigate a nearby site for another project on our route back. A short survey, a little video and we were done. I surfaced to mark the position on a rock and decided to scooter back on the surface, leaving mask issues happily behind and feeling distinctly underwhelmed by the dive.*

Arriving home and handing over the bag, we realised that hydrophone #2 was missing. After some frustrated searching of the car and the shore site the next day, it was time to admit it was lost. I played back the dive, felt sure that it had been retrieved, confirmed by the memory of the second diver, but that it had fallen from the bag on the way back.

The next step was a search on open circuit of the lake bed under my route back to the exit point, the survey shelf and the boulder scree from there to shot #1. Searching the boulder scree was complicated by the 1.5m high plant growth. 85 minutes of fingertip searching later and all we had was an empty can of Thatchers gold cider. This confirmed that our technique could find an object of the correct size.

My mind began to suggest that the bag had not been as 'full' as usual at shot #1. Also, the fact that hydrophone #2 had fallen out past hydrophone #1 which was put in after #2 didn't make sense.

Two divers searched from shot #2 to shot #1. Over this short distance, they searched slowly from 2m down to 18m through the plants. No hydrophone was found.

It was a few more days before the next search could be made. In that time, I revisualised the dive several times. The hydrophone was not only valuable in itself but contained a years' worth of PhD data for my wife. The stakes felt elevated, but the fact that this was a lake of finite dimensions remained as the only reassurance. I was convinced that I had removed the hydrophone, and had a distinct strong memory, both mental and physical of steering the DPV away from shot #2 to shot #1. The second diver had been to my right at this point and always had a clear view of the hydrophone removal, but this time, had nothing helpful to add.

We finally got back in the water for another search about 10 days later. The plan was simple. Go to shot #2, descend and search to shot #1, then retrace the exit route again. My buddy dropped down the shot to the boulder scree and plants at about 4m, while I descended the shot to a clump *of vegetation at approximately 2m. Passing this, I found the hydrophone, attached by all three cable ties. I had never removed it. We turned the dive, elated but with some serious post dive / mission analysis to complete.*

Running back over the dives to review why such a simple mistake had gone undetected was humbling. I had always prided myself that I had never lost an item of scientific gear and had strived to improve my technique over a quarter century of working underwater. I had begun scientific diving as a single tank diver looking like a Christmas tree covered with quadrats, current metres, slates and sometimes video, graduating to an organised CCR and DPV platform with gear placements reviewed, visualised and worked into a dive plan that allowed normal function and good emergency reaction. We had dived as a team, with signals and confirmation of tasks complete - no 'same ocean' buddy system here. It had worked fine over a sequence of dives. How had I simply not removed hydrophone #2, and more importantly, why had post dive visualisation not provided more information?

In Tim's case, there were a number of factors at play which led to a series of 'errors' being made and one error which then had pretty large consequences given the efforts required to recover the 'lost' piece of equipment. These factors included having done the job numerous times before, so both physical and mental 'muscle memory' played a part in what 'would' happen (expectation - see Chapter 7, Situational Awareness, for more on this) the mask leaking which provided a little distraction and minor workload on top of an emotionally important task - the research data was for his wife! What is interesting is that the buddy should not have been subject to the same stressors as Tim, but there are likely other reasons why the buddy missed the hydrophone - they were taking their lead from a very experienced diver (Tim) and also the fact that the buddy was employed by Tim as a dive instructor. The presence of authority gradient has shown to be causal or contributory in nature in aviation, maritime and healthcare accidents such as the Tenerife crash of 1977 or the Costa Concordia grounding and capsize in January 2012. So, while a simple 'human error' occurred which led to the dive ending with the perception that the hydrophone had been lost, the reasons for this are pretty complex. This chapter will look at what human error really means and why it is important to be able to distinguish between the different types of errors and violations or 'at risk behaviours'.

Human Error

Human error can be viewed through one of two lenses. We can see human error as a cause of failure, or we can see human error as a symptom of failure. Unfortunately, the first is the most prevalent. However, as we will see, if we don't consider the second view, we won't improve safety too much because we won't go beyond blaming the individual.

In 1990, Professor James Reason wrote 'Human Error' and he clearly articulated that such a simplistic term adds little value to learning by attributing it as a single cause to an accident. In the 1970s and 1980s, numerous accident reports and research papers stated that 80%-90% of aviation accidents were caused by 'human error'. The same attribution has been applied in medicine and other high-risk domains. However, since the 1990s the aviation operational and research communities have recognised that this attribution is flawed because 'human error' is normal and using a simplistic term does not help learning when specific details are needed to understand the context. The same goes for 'violations' as a cause for accidents - without understanding the reason for the violation, the system will likely create the circumstances in which the diver (human) has to make a similar decision or subconscious 'choice'.

Human error as a term is traditionally broken down into the following categories: slips & lapses, mistakes and violations.

- Slips and lapses are where actions deviate from the current intention due to a failure to execute the action as planned and/or memory storage failures (forgetting)!
- Mistakes are where the actions may run according to the plan, but where the plan is inadequate to achieve its desired outcome. Mistakes can be further broken down into rules-based and knowledge-based mistakes, the categories providing an insight into why the mistake was made.
- Violations are where a 'rule' or 'standard' has been broken intentionally. However, as will be explained in this chapter, determining error or violation in a manner which allows learning to take place (not just attributing blame) is not a simple task without providing an additional vocabulary. We need to understand the local rationality, why it made sense for the individual to 'break the rules', if we are to improve performance and safety.

The chapter will also highlight the challenges involved in undertaking incident investigations due to a lack of data, a poor *Just Culture* and that just attributing 'diver error' without looking at the wider system context (the 'how it made sense') means that the same errors will continue to occur.

Slips, lapses, mistakes and violations/non-compliance

It is sometimes hard to discern the difference between the different types of human error and violations/non-compliance in diving and there are very good reasons for this. Firstly, we lack details in incident reports and so we can only focus on the outcome, secondly, the observer's position biases the perspective i.e. who are they and what is their position and/or experience, and finally, there are so many 'standards' in the diving industry that what is right for one person or organisation is wrong for another.

The following example of driving above the speed limit will highlight the different factors to consider. As speeding is such a common occurrence, we do not always see it as a human failure. Being clear about the reasons why it might occur can help create a better understanding of errors and violations.

Some reasons why people speed include:

- Driving someone to hospital - under normal circumstances we might not speed but because we are driving someone to hospital we consciously decide to break a known rule - this is an exceptional non-compliance.
- We always drive above the speed limit - we believe that it is okay to speed and do so habitually - this is a routine non-compliance.
- We drive with the speed of surrounding traffic - the speed of the traffic around us, tail gating drivers and aggressive overtaking encourage us to speed when we would normally stick to the speed limit - this is a situational non-compliance.
- We misread the speedometer - this is a slip or lapse.
- We do not realise we are in a 30mph speed zone - this is a rule-based mistake.
- We forget we are in a 30mph speed zone - this is a slip or lapse.
- We are distracted by the passenger - this is a slip or lapse.
- We are in an unfamiliar car - we are not used to the car driving so smoothly and we are not aware we are speeding - this is a knowledge-based mistake.

Therefore, it cannot be assumed that an observed failure, such as speeding, is always a non-compliance. Speeding may be an error or a non-compliance - the reason for the non-compliance may also change depending on circumstance. In diving, we don't often capture the rationality, and so we often jump to the conclusion that it is always a violation or non-compliance and should be punished in some form or another. Chapter 5, on *Just Culture,* will cover this in more detail.

If all events are treated in the same way, the problem is unlikely to be rectified. The root cause(s) of the problem should be understood - for example, if people are speeding because they do not realise they are in a 30mph zone then a good solution might be to make speed limit signs much clearer, or introduce vehicle activated signs that flash when there is a speeding car. This is likely to be more effective than training people about the rule (which they may already know and understand). I was personally caught this way in the US as I missed the single road sign as I left a built-up area and joined a road which looked identical to the one I entered the town on. The limit was 65 going into the town and reduced as I reached the built-up area. As I left the town, the road was of a similar construct, two lanes on each side without a central reservation. The traffic was moving approximately the same speed as before too. As I was overtaking a car I noticed a Sheriff's car behind me and they flashed me. I was doing 15 mph over the limit and not the 5 I thought I was. After paying my fine, I continued on my journey. I noticed that the same road could be a 30, 40 or 55 mph but that there was only a single sign at the transition point. In the UK, if the road has a much lower speed limit than would be expected for the road design, then there are regular signs highlighting that you are in a different speed zone. This need to address human performance in system design is core to the science and practice of human factor.

When we read about diving incidents in the social media or accident report summaries written by organisations such as *Divers Alert Network* or the *British Sub Aqua Club,* we often read the term human error being used as a way of explaining why the accident or incident happened. Indeed, this attribution also extends to diving research papers and literature. However, modern safety literature and research has shown that such attributions do very little to help improve learning, develop future performance and prevent future accidents. This chapter will explain why.

Digging into the detail

High-risk domains such as aviation and nuclear have contributed massively to the research into safety, human factors and human performance because failures or adverse events can have such massive effects in terms of the loss of life, as well as social and environmental impacts. Over time, tools, models and frameworks have been developed which provide additional levels of granularity or detail into why and how the unwanted event occurred at the individual level e.g. *Generic Error-Modelling System* (GEMS) (slips, lapses, mistakes and violations) or to look further back in time or up the organisational 'tree' with tools such as the, *Human Factors Analysis Classification System* (HFACS) and *Root Cause Analysis* (RCA). However, even with all of these tools, it is very difficult to adequately explain the unexpected and unwanted interactions within a system which lead to an accident because of the emergent nature of failures. More powerful and resource intensive tools like, *Systems-Theoretic Accident Model* (STAMP) and *Functional Resonance Analysis Model* (FRAM) have been developed which look at interactions within a system.

Despite the availability of the simple tools, there has been no published application of the use of such formal tools to investigate a diving incident or accident and only simple outcome models or categorisations are used. The problem with simple models is that they often hide the reality. e.g. in the *British Sub Aqua Club* incident report a diver who runs out of gas due to distraction or high workload, who then has a rapid ascent which leads to decompression sickness (DCS) would have their incident categorised in the annual report as a DCS incident and yet these are *just* outcomes. Another example would be the research by DAN which showed that 41% of the fatalities which they could attribute triggers to were caused by insufficient gas[1]. However, without understanding why the gas ran out doesn't really help you prevent future incidents because we all know that being underwater without a breathing gas supply is likely to end up as a fatality or serious injury. Context is vitally important if safety and performance are to be improved.

Paradoxically, research by Olsen and Shorrock focusing on Air Traffic Controller performance showed that as more granularity or detail is added to a framework, schema or taxonomy to help define the causal and contributory factors, the less reliability there is in terms of a consensus of opinion from those doing the assessments. This is because each observer of the system will have

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[1] Denoble, PJ, Caruso, JL, de Dear, GL, Pieper, CF, and Vann, RD, 2008. Common causes of open-circuit recreational diving fatalities. *Undersea Hyperb Med*, 35 (6), 393–406.

their own experiences and expectations about how something should be done, and it takes considerable training and a diverse investigation team to isolate personal biases from the investigative and analysis process. In simple, linear problems, it is easy to define a standard, but when problems are encountered with conflicting goals of time, resource and outcomes, then it isn't so easy to define 'what is right'. As a global diving community, operational standards are few and far between and even when looking at diver training, the lack of active quality assurance and quality control means that operational drift is more likely to occur, even if the initial certification/qualification process was intense and of a high quality.

Furthermore, the research also shows that depending on the perspective of the reviewer, a certain topic of interest will be the focal point for where errors are 'discovered' e.g. during research which looked at the errors made by air traffic controllers, observers consisted of a mixture of psychologists and specially-trained air traffic controllers. The observers who were air traffic controllers noticed problems related to the equipment, the messages being relayed and the radar plots etc, whereas the psychologists were focussing on cognitive issues and how decisions were made. Ironically, when operators who were looking at the 'events' with a view to improving performance were questioned about what they saw, they recounted that the operational controllers were finding ways to adapt to the dynamic situation they were facing, even if that meant they were having to 'break rules' or 'cut corners' to achieve their goals, goals which are often in conflict with each other. As such, understanding the perspective of both the reviewer and the person(s) involved is essential if we are to improve safety and performance.

A simple, reductionist approach does very little to achieve an improved level of safety, especially when observers have the benefit of hindsight and know the outcome. They can easily join the dots which weren't apparent to the diver at the time. If they were apparent and noted as relevant, then they would have been acted upon. Therefore, in the context of this book, human error when used as an attribution for causality is placed inside inverted commas to identify that it is a generic term and not a specific one.

Richard Lundgren's account below of a near-miss in which a diver could have easily died due to breathing a gas which wasn't compatible with life shows that it isn't just the 'error' which the diver made that we need to look at, but the context and the drivers involved which led to the situation developing in the manner it did. The WITH model[2] of error producing conditions will be explained more in Chapter 11 of the main book as this provides a good guide for those in supervisory or leadership positions to be pro-active in their risk management.

Case Study: Searching for the Admiral's Fleet

In the mid-nineties, I was part of a major project to search for the Swedish admiral's lost fleet, a project which has been going for three years and would go on for many more. The next trip was about to kick off and we had perfect weather for it. Dead calm seas and bright skies. All those present had a positive feeling caused by the previous day's successful wreck hunt where a new promising target was found. This day we had the chance to make history and we were all eager to claim it!

Little did we know that it all could have been so easily put to an abrupt and unexpected end because of what happened in the next 60 minutes.

One diver, who will remain nameless, was arriving late having been delayed due to a long and complicated trip down to the island we were operating from. Initially, the unwelcome delay caused some amusement among the waiting divers, but the sensation soon turned to frustration and anxiety.

When he finally arrived, we were now seriously delayed. The diver excused himself and started to pack his gear into the boat, eagerly assisted by the other divers who were all now well motivated and ready to leave the dock. Drysuit, fins, wings were all quickly moved from the truck assisted by many helping hands. Also, doubles and decompression bottles….

"Hey, what are you doing? Stop that!" I was the surface manager that day with the task of ensuring that everything loaded on the boat was as it was supposed to be. My language was direct and my mood grumpy due to the delay, and there was a building fear that we would miss the opportunity waiting for us.

"Why should we stop? We need to get going!" one of the other team members called out, feeling equally frustrated and eager to get going as I was.

[2] The WITH model has been derived from the nuclear industry and looks at conditions which are likely to lead to errors being made. The letters stand for Work (the physical work environment including social pressures), Individual (the individual worker's traits/behaviours/limitations), Task (the complexity of the task and processes/rules associated with it) and Human (normal human fallibility and cognitive biases).

"The tanks need to get out of the boat, now! They are not marked!" I said.

"Chill out will you, they are all good to go! Don't be such a bureaucrat!" the delayed diver angrily replied, siding with the crew in an attempt to deflect some of the criticism for being late.

"We are going nowhere until the tanks are all off the boat, pressure checked, analysed and marked up! Stop messing around wasting time! Do it!" I roared.

There were no helping hands this time as the now furious, delayed diver had to unload his cylinders and start the verification process. There was lots of mumbling and swearing. All tanks checked out fine, they were properly marked and loaded back into the boat. All, bar one that is.

"Dammit, I forgot to fill the oxygen, the cylinder is empty!" Said the delayed diver referring to his oxygen decompression cylinder.

The team's massive frustrations were made very clear to the delayed diver.

"Go get it filled then, take your time" I said now more under control, trying to be calm as I realised that the situation was quite stressful, and that stress promotes mistakes.

As the diver walked away with the cylinder in order to use the fill station situated in one of the harbour facilities, the other divers were obviously complaining due to the further delay. It was easy to understand their feelings but at the same time we needed to be better than this. The situation was stressful for all of us - me, the divers and mostly for the delayed diver.

"Hey, get your own stuff together, double check your gear and be ready to depart rather than complaining!" I said conversationally, trying to reduce some of the tension.

"We almost lost the day because of this!" one diver shouted.

"We will lose more than that if we continue making mistakes like this due to stress." I replied.

The delayed diver came running back carrying his refilled decompression bottle and started to board the boat.

"Hey, not again! Get that tank marked properly!" I said with a stern voice.

"Come on! I just filled the cylinder with oxygen myself! It is analysed, I've just not had the time to mark it! It's OXYGEN, get it?" he shouted furiously.

"XxXxxxxXXXX!" shouted the waiting divers in despair.

"Seriously! Either you do what is expected of you or we are departing without you! Final chance!" I made this statement calmly to prevent the others overhearing what I had just said.

"I don't have the darn analyser, I forgot it at the fill station!" said the delayed diver.

"Here you are, use mine!" I said and handed over my analyser.

The diver calibrated the analyser and started to analyse his oxygen decompression bottle.

"Ha, your analyser does not work!" The delayed diver shouted in a high-pitched stressed voice.

"Well, how come?" I queried, mystified.

"It's reading zero! You should really take care of your equipment better!" The delayed diver said, now challenging me.

"And your pressure?" I asked.

"185 bar! Your analyser is not working! Let's be done with this and just go! I know it's OXYGEN!" Stated the delayed diver.

"Nope!" I said casually.

The delayed diver deployed the regulator attached to the oxygen decompression cylinder in rage, pressurised and started to breathe forcefully from the second stage.

"You see, nothing wrong with the gaaaaas….!" screamed the delayed diver in a high-pitched helium voice before he lost his balance and sat down hard on his butt.

In aviation it is recognised that human error happens all the time. It has been reported that between 3 and 6 errors per hour occur on the flight deck, but they are all (or nearly all) trapped before they become an issue. In fact, one researcher showed that a crew in a simulator made 162 errors during one flight, but only discussed one of them in the debrief because they didn't think the 157 errors made while operating the flight management system counted as they didn't think they compromised safety![3] Given that errors are normal, the aviation community has built on the concept of *Crew Resource Management* (CRM) and developed the *Threat and Error Model* (TEM) which looks at when errors are more likely to happen and modify their behaviours accordingly, especially when it comes to communications and teamwork.

In the case of the incorrect filling of the cylinder with 100% helium instead of 100% oxygen above, we can see that having procedures in place, procedures which are non-discretionary in nature, can save people's lives because they trap errors before they can propagate to an end state of a fatality. Unfortunately, as will be described in Chapter 10 (Leadership) the absence of such

[3] Amalberti, R. Wioland, I. 1997. Aviation Safety: Human Factors. System Engineering. Flight Operations. Economics. Strategies. Management. p94

robust procedures cost Carl Spencer his life. Carl was the expedition leader of the 2012 Britannic expedition and because he was so busy running the expedition, he made a number of critical errors and there was no ability to fail safely. He died of oxygen toxicity after he breathed 50% at 40m – the bottle was not marked as a 50% bottle.

Such procedures and concepts are useful, but they need to be tempered with what happens in the real world. As such, there is an essential need for a feedback loop to ensure that instances of 'errors' and 'at-risk' behaviours can be considered as part of the system design.

The Sharp End and the Blunt End

Within any system involving people, there is a 'sharp end' and a 'blunt end'. The 'sharp end' consists of those people who execute the plan against the 'rules' of the game which have been written. The sharp end could be:

- pilots who have to operate their aircraft in line with the safety procedures and protocols published, cognisant of the time pressures to maintain a schedule and financial pressures to minimise fuel burned, or,
- surgeons who have the patient's safety at heart but also need to balance the pressures to reduce waiting lists and use equipment which may not have been designed with the operating theatre team in mind, or,
- in the case of diving, instructors and dive centre owners who have to balance training procedures with real world pressures to maintain commercial viability in a cut-throat environment or,
- divers who have to balance their spare time available with the disposable income for a discretionary leisure activity which might mean that they don't service their equipment when they should or undertake continuation training to ensure their skills are at the level they should be.

The 'blunt end' consists of those in the organisations who write the international, local, organisational and company standards, policies and 'rules' which the 'sharp end' must use to execute their role. Often those in these positions have very little contact with those at the 'sharp end', which means their view of the world is different.

To explain this apparent disconnect, a concept exists called ‘Work as Imagined/Work as Done’ in which there is a difference between what system and equipment designers and managers imagine should happen or should get done at the ‘sharp end’ and what actually happens, given the conflicting goals which have to be balanced in real time. As long as nothing goes wrong, the ‘Work as Imagined’ appears to be correct, although adaptations and modifications are happening all the time. However, if something does go wrong, there is an immediate comparison between ‘Work as Done’ and ‘Work as Imagined’ and it is normally the user/operator who is blamed for not doing something correctly, even if doing the right thing is not possible because of the system’s constraints.

There is always a conflict between the ‘sharp end’ and the ‘blunt end’, mainly because of the goals which need to be managed and the resources allocated to achieve them. When things go wrong, it is easy to think it is the fault of those at the ‘sharp end’ who have ‘caused’ it and yet those at the ‘sharp end’ are normally the ones who have inherited the flawed rules, procedures, hardware and equipment from those at the ‘blunt end’. Furthermore, it is normally those at the ‘blunt end’ who undertake the investigation to determine where fault lies within the system and human nature means that often we aren’t introspective and, so again, the fault lies with those at the ‘sharp end’! Closing the gap between ‘Work as Done’ and ‘Work as Imagined’ is essential if safety and performance are to be improved. However, that doesn’t always mean moving ‘Work as Done’ closer to ‘Work as Imagined’; first there is a need to understand why the deviation is in place to start with.

As such, it is very easy to think that by attributing ‘human error’ to accidents, that we have solved the problem. In fact, if the term ‘human error’ ends up in an accident report, it means one of a number of things: The authors (or those who commissioned the report) are happy with a ‘catch all’ that doesn’t permit detailed learning to occur, or that they stopped investigating: either because they didn’t want to find the answer, or they didn’t have the resource (time, money or data) to find out how something happened. Often, it is much simpler to blame the fallible human because the more we blame those at the ‘sharp end’, the less we have to do to examine the ‘blunt end’ and find the systemic failures which are present. If ‘human error’ is consistently attributed, it probably says more about the organisation or culture than it does about the individual.

The components of 'Human Error'

Notwithstanding the above, there is a need to have some means of helping to categorise broad 'buckets of information' so that we can identify trends or systemic failures, even if the categories are not experienced in a linear manner. Indeed, on closer examination, often it is the convergence of many, apparently, unrelated factors which create an accident. This categorisation process is where taxonomies or frameworks can help. James Reason in his book, *Human Error*[4] provides an insight as to how human error could be defined with his *Generic Error-Modelling System* (GEMS) to look at the basic human error types (slips and lapses, mistakes and violations). This system is based on looking at how failures occur against the basic human performance model by Jens Rasmussen (skills-based, rules-based and knowledge-based decision making).

Reason describes how these three error types were matched against three different performance levels by Rasmussen - skills-based for slips and lapses, rules-based for rule-based mistakes and knowledge-based mistakes. Reason explains that to understand which performance level was being used (Skills, Rules or Knowledge) the question should be asked as to whether or not the individual was engaged in problem solving at the time an error occurred. In his model, Rasmussen states that behaviour at the skills-based level *"represents sensorimotor performance during acts or activities that, after a statement of an intention, take place without conscious control as smooth, automated, and highly integrated patterns of behaviour*[5]*"*. Reason goes on to describe that although skills-based performance can also be invoked during problem-solving to achieve local goals, such behaviour is primarily a way of dealing with routine and non-problematic activities in familiar situations. Both rules-based and knowledge-based performance on the other hand are only called into play after the individual has become conscious of a problem i.e. the unanticipated occurrence of some externally or internally produced event or observation that demands a deviation from the current plan. In this sense, skills-based slips generally precede the detection of a problem, while rules and knowledge-based mistakes arise during the execution phase. Thus, a defining condition for both rules and knowledge-based mistakes is an awareness that a problem exists. In diving, this can be an issue because a fair amount of training is conducted

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[4] Reason, J.T., 1990. *Human Error*. England: Cambridge University Press.

[5] Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man, & Cybernetics, SMC-13*(3), 257-266.

in the ‘learn, observe, practice’ (akin to Bloom’s Taxonomy of Education Objectives – levels 1 to 3) rather than understand the ‘why’ behind the action (levels 4-6).

A practical example of this would be a second stage free-flow which necessitates a shutdown while diving a twinset. The diver recognises from the noise and bubbles in their face that their back-up regulator second stage is free-flowing (skills-based), they reach back to the right post to shutdown (rules-based) and start shutting the valve down by turning the valve clockwise (skills-based). However, the free-flowing doesn’t stop (rules-based) and so they go to shut down the left post without opening the right post (rules-based mistake). The diver shuts down the left post and subsequently runs out of gas. They now have to work out what has happened and what to do about it (knowledge-based) and then execute the action (skills-based).

As we can see, moving from one type of behaviour or performance level to another happens dynamically and therefore categorising issues (Skills, Rules or Knowledge) in real time is difficult. However, what Reason shows is that the error rates associated with the different decision-making processes are different and, as such, this demonstrates the need for training which provides divers with the ability to work at the different performance levels.

- Skills-based: This is determined to have an error rate of approximately 1:10 000, where errors are normally associated with distractions and the cognitive flow for the ‘automatic’ behaviour is interrupted. e.g. the button on the inflator hose to deflate the wing is pressed instead of the inflate. Skills-based performance is improved through deliberate practice, repeating the same skills with feedback to ensure that not just ‘practice makes perfect’ but ‘perfect practice makes perfect’.
- Rules-based: An error rate of approximately 1:100 is present and this is normally caused by applying the wrong rule to the current situation. Rules could be technical or social in nature. Using the above example regarding the shutdown drill, the diver did not follow the correct rule (open right post before shutting down left post). Rules-based performance is improved by exposing divers to different scenarios with subtle differences so that the different rules can be identified and then applied. As greater experience is developed, these activities move into more skills-based performance.

- Knowledge-based: Error rates of between 1:2 and 1:10 are experienced. This is predominately because the operator does not have the experience or knowledge about how to solve the problem. At worst, it could be a 50:50 guess as to the solution. The challenge is how to improve decision-making in this domain because there is a finite amount of time/money to learn everything and be exposed to every failure mode during a diver training class. However, what can be done is to develop an understanding of why certain things are done a certain way which allows the operator to think around the problem rather than have a direct answer. For this to be effective, the instructor needs to have a high-level of knowledge to teach not just rote responses (rules-based).

Summary

Human error is around us all the time. We are all fallible. Even the most experienced amongst us. The difference between 'experts' and 'novices' is that the experts will pick up, anticipate, detect and correct small errors before they are anywhere close to a critical failure.

We need to recognise that different performance levels have different error rates, as well as different reasons why the errors happen. In skills-based decisions/performance it is normally distraction that causes an error to propagate. Therefore, something which keeps the focus in the right place and slows us down when in a critical environment is needed e.g. written checklists which are followed, or team accountability for when verbal checks are used. In rules-based decisions/performance, we need to understand why the rule is in place and not just look for confirmatory evidence to prove we are doing the right thing, but to look wider and understand the context e.g. just because the plan said to have a bottom time of 35 mins, as the current has picked up and we will use more gas returning, we need to turn the dive at 25-30mins. Finally, when looking at knowledge-based situations, don't be surprised if errors occur. If someone has never been exposed to such a situation before, why would they know what to do? They can resort to a rule-based decision, end the dive, but the circumstances might not allow that e.g. their buddy/guide/instructor won't end the dive and so they have to consciously work out what to do, balancing the competing goals they have.

Chapter 6: Decision-making in Diving. 'Choices' are not what many perceive them to be.

"When any one asks me how I can best describe my experiences of nearly forty years at sea I merely say uneventful. Of course, there have been winter gales and storms and fog and the like, but in all my experience I have never been in an accident of any sort worth speaking about. I have seen but one vessel in distress in all my years at sea. I never saw a wreck and have never been wrecked, nor was I ever in any predicament that threatened to end in disaster of any sort. I will say that I cannot imagine any condition which could cause a ship to founder. I cannot conceive of any vital disaster happening to this vessel. Modern shipbuilding has gone beyond that." - Captain EJ Smith, the Captain of the Titanic.

The following account is from Ryan Booker, one member of a team of four experienced cave and technical divers, three of whom were also recreational diving instructors. Their goal, to get one of the team members diving after spending several years recovering from a serious injury. The outcome? Goal achieved, but with serious risks and a very close call.

Case Study: How easy is it to say no?

After several false starts, and several years of painstaking recovery, this is the day. We are going diving. The gear is ready, we are ready.

We've taken into account the issues his accident has left him with. Less mobility. Less strength. We have twin 7s instead of twin 12s. We have a scooter. We have a solid team who've all dived together many times before.

We've surveyed the site.

Our first chance to abort: It is a spring tide and running fast. More than usual, and past the normal slack window.

Second: It is dirty water. Rain during the lead up has dropped the visibility significantly.

Are we ok with this? Of course. We're experienced. We've been looking forward to this for years. Why back out now? Three.

We're geared up. We're in the water. "We still good?", "Yep, stay close". Four.

Descend.

May as well be zero vis. The buddy teams are separated. Five…

We abort and ascend.

"What should we do?". Six.

One buddy team: "We're getting out". Seven.

Buddy team with injured diver: "Still good?". "Yep". Eight.

We descend. Stay close. Touch contact. Scooter for a while, in the direction of some interesting features we know of. The current is strong. Stress is high. We decide to abort. Again.

We break touch contact to shoot a dSMB. We can just see each other. We end up on a navigational pylon in the middle of the boat channel, the dSMB tied around it. Not where we expected. There's a ladder. I grab it. The injured diver surfaces a little off the pylon. Scooters back. I'm really glad we had that scooter. He wouldn't have made it otherwise.

We signal that we're ok, I take the scooter and tow him back to shore.

We get out.

We have quite the debrief.

Hindsight is 20/20.

This was a classic "goal oriented" failure. We built the event up so far, and had already made so many attempts, that we simply couldn't be dissuaded until it was almost too late. We had so many clear reasons to abort the dive, and opportunities to do so, but persisted, to almost catastrophic results. We achieved the goal, but it's hard to think of it as a success in any other metric.

We all knew it was a bad idea, and we all sensed the escalation. Two of us had a slightly lower threshold or perhaps pigheadedness. But we all knew. Yet none of us took control with any confidence.

It was a failure of planning, of leadership, of followership. A failure to speak out. A failure to listen to the non-verbal cues. An overconfidence in our own abilities.

We learned a lot. Thankfully with limited consequence.

As Ryan’s account highlights, sometimes humans aren’t very good decision makers! Most of the time we make acceptable decisions. On a few occasions we make amazing decisions. But the ‘choices’ people make when they are caught up in the moment are rarely choices, rather they are a product of the experiences they have had previously (good and bad) the knowledge they have gained from experiential learning, from the information they have gained from learning in a passive manner such as reading or watching videos, and finally from the hard-wired genetics and physiology which makes up the human body and brain. Understanding how decision-making actually happens is essential if we are to improve our own performance and safety in diving.

This chapter will describe the different decision-making models and processes we use (Skills/Rules/Knowledge, System 1/System 2, Naturalistic Decision Making and Biases & Heuristics) their strengths and weaknesses, how to overcome some of the cognitive limitations we have through the use of checklists and ultimately give you the skills to make more effective decisions both topside during planning, but also underwater while on the dive.

Decision-Making

Decision-making has been defined as the process of reaching a judgement or choosing an option to meet the needs of a given situation. It can be broken down into the following main areas - understanding the situation at hand/defining the problem, determining a potential course of action or the option(s) available based on the information immediately at hand, selecting and executing that option and then undertaking some form of review process to determine if the decision was effective in terms of the goals set, and then repeating until the goals have been met.

This might seem like common sense because decisions happen every minute, every hour and every day of our lives and yet many of them we don’t even realise we are making as they are made subconsciously and they are subject to biases and heuristics (mental shortcuts) even those which take many days or weeks of deliberation to come to a conclusion, once we have weighed up all the ‘facts’.

The environment, task or time available mean that different decision-making techniques are available and can and will be used. The ability to recognise the strengths, weaknesses and biases of the different techniques leads to an effective decision maker who can undertake critical thinking. It is important to note that the ability to be a critically-thinking decision maker doesn’t just reside with the leadership. One of the key skills for an effective follower is to be able to honestly and robustly apprise their leadership and peers to ensure that decisions are in line with the current goals.

In high-risk industries, there is significant research which identifies that poor judgement or ineffective decision-making were contributory factors to accidents. For example, between 1983 and 1987, research showed that these factors contributed to 47% of accidents in aviation[6]. In the oil and gas domain, *Piper Alpha* and *Deep Water Horizon* disasters both happened due to ineffective decision-making. However, we need to recognise that hindsight bias is easy to apply when examining accidents and near-misses because we have more facts than those involved. Daniel Kahneman uses a term which sums this up nicely "What you see is all there is" (WYSIATI)[7] to highlight that when we make decisions in real-time, we only have the externally-generated information that we have perceived as being important or relevant and we apply previous experiences to make sense of that information; once we have made sense of the information, we apply it to make a decision. So, when something goes wrong, fundamentally, at that moment of decision-making, it makes sense to us to make it, as we have based it on the information that is currently available to us in that moment i.e. on what we know. This is known as local rationality. Consequently, to make better decisions, we need to understand the limitations of the decision-making processes we use, what external or internal factors can influence a good or bad decision and learn tools which help us improve those decisions.

Critical decision-making is a skill which is essential to high-performing individuals or teams and understanding the strengths and weaknesses of our decision-making means we are better prepared for the times when uncertainty and ambiguity is upon us.

Understanding these limitations, developing and deploying ways around them was one of the reasons why Cockpit (now Crew) Resource Management training started to be embedded into aviation training programmes in the 1980s. Following the success of such programmes in that domain, a number of different Non-Technical Skills training programmes have been developed in other domains.

- Healthcare. Non-Technical Skills for Surgeons (NOTSS), Anaesthetists Non-Technical Skills and TeamSTEPPS.

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[6] Flin, R. O'Connor, P. and Crichton, M. 2008. *Safety at the Sharp End*. Ashgate Publishing.
[7] Kahneman, Daniel. Thinking, Fast and Slow (Kindle Location 1454). Farrar, Straus and Giroux. Kindle Edition.

- Maritime. Bridge Resource Management (BRM)and Human Element Training (HELM).
- Oil and Gas. Well Operations Crew Resource Management (WOCRM) programme.

The only such programme developed specifically for recreational, technical and cave divers is the one I have developed and deployed globally via, 'The Human Diver' and you are reading the only text book which considers this topic.

As you progress through the chapter, you will notice that there is quite a bit of an overlap between the different theories when considered at a practical level. You should also notice the influence of other non-technical skills, and how they can impact on the effectiveness of our decision-making. Therefore, learning about and practicing decision-making in isolation won't necessarily make an overall improvement to you, your team or 'the system' - making a decision is not enough, it needs to be communicated, executed and followed up to ensure the result is what you expected it to be.

Mental Models

The world is a really complicated and complex place and we humans would prefer things to be much simpler. So, what we do is create mental models which act as a way of reducing reality to something which is 'good enough'. A road atlas is an example of a model which is 'good enough'. It is good enough because we don't need to have a high-fidelity image of all the bumps, turns, lane layouts and signage. This simplified model of reality allows us to drive hundreds of miles across the country without too much of a problem or without too much mental effort.

A cave map does the same job, it provides the cave diver with enough detail to get from the entrance to the exit in a safe manner highlighting areas of interest - interest which might be for aesthetic or enjoyment reasons, or it might be because there might be a restriction or problem that needs to be addressed when the diver gets there. Either way, it helps the divers make effective decisions without giving them too much information to process. However, for them to be effective, there needs to be some form of translation available. I am not a cave diver and so if you showed me a cave map, without a key to explain the symbology, the map (model) would have limited use.

Our mental models do the same thing. They provide a simplified model of the world which allow us to undertake activities without diverting all of our cognitive resources to the situation at hand. This reduction in mental workload means we can do other things, like dive and have fun in the process.

As an example of how models develop over time, we are driving our car and waiting at cross-roads to turn right across the oncoming traffic. This already invokes a mental model and one which might not be valid for you. If you are not used to driving on the left-hand side of the road, this would be counter to your mental model of 'turning across traffic' because turning across traffic means turning left!

As the traffic is coming towards us, we are looking for gaps to pass through. We don't know the speed of the traffic coming towards us, nor do we know the exact distance between the cars, but we have a mental model of what a 'big enough' gap is supposed to be based on our previous experiences. When we were novice drivers, the gap we would use would likely be much larger than one we would use now because we have more experience and have reduced the uncertainty involved. We find the sweet spot for these models by failing, making mistakes, and having a feedback loop which then informs our future decision-making processes.

So how does this relate to diving? When we ascend and want to stop at a certain depth to complete a decompression stop, we dump gas from the *Buoyancy Compensation Device* (BCD) or wing to arrest the ascent. The amount of time which we hold the dump valve open to let the gas escape is based on previous experiences, either during training classes or 'fun dives'. Over time we refine this action, so we can pre-empt the dumping process (i.e. the time the valve stays open and the depth below the stop when we start opening the valve) and we stabilise at the right depth 'without thinking about it'. However, if you change the parameters, like being much heavier because you are now diving multiple nitrox-filled cylinders instead of a twinset or twinset with helium mixes, then the amount of gas which escapes when you hold the dump valve open for a 'normal dive' is much more and you stabilise early or sink because too much gas has escaped. I know this because it happened to me during my advanced trimix class during the initial skills and ascent training phase. Instead of helium-based mixes in the twinset on my back and the bottom stage, they were filled with Nitrox 32% which weighted considerably more than the helium-based mixes.

Another example is when divers use primary lights for communication. The rapid movement of a primary light from side-to-side is indicative of an emergency situation and the diver could be out of gas, so the buddy turns to see what is happening and gets ready to donate their primary regulator. However, if a diver uses a primary light but does not understand that the light should be kept stable and not moved around in a manner which wouldn't look out of place in a scene from an 80s disco, their buddy or others may think there is an emergency and turn to help. The more this goes on, the more the buddy gets frustrated and a 'cry wolf' response soon develops. As such, the mental model of 'fast moving light means emergency' changes to 'annoying buddy who can't control their light'! However, if there is a real emergency, the buddy will likely take longer to respond in a proper manner.

As divers we need to recognise the mental models we use all the time. They exist topside when communicating with others, when we are in the water on a dive and interacting with our buddies, or when we are observing the world. These mental models are essential for humans to live in the world we do. Our fight or flight responses are based on mental models which have been created over millennia of learned behaviours and we can't easily turn them off. Training can help reprogram them, but it takes significant effort to unlearn and then relearn, especially if we are in an alien environment like diving where previous models might not be valid, like opening your mouth to breathe when underwater and you are out of gas…!

Cognitive Biases and Heuristics

What are the answers to the following three questions?

- A bat and ball cost $1.10. The bat costs one dollar more than the ball. How much does the ball cost?
- If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? 100 minutes OR 5 minutes?
- In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? 24 days OR 47 days?

These questions are part of a *Cognitive Reflection Test*. Research using Stanford University students showed that 90% of them made a mistake in at least one of the questions. How did you do? The answers are at the end of this chapter.

The reason for the high error rates is that we take mental shortcuts when we make quick decisions, shortcuts which are based on previous mental models. In the first question, we make a mental jump from $1.00 and $1.10 as being a 10¢ difference, and therefore that is the answer. In the second example, we are looking at repetition of numbers. In a similar way that if I flip a fair coin 10 times and I get 10 heads, the normal response would be for a head to be the answer for the 11th flip because we expect it to happen that way. Finally, for the last question, half of 48 is 24, therefore that must be the answer. Mental shortcuts appear in multiple case incidents and accidents. Often, we say 'assumptions make an ass out of you and me', but in many cases they don't and we need to understand which are the critical ones so we can slow down.

Unfortunately, or fortunately depending on how you look at it, there are hundreds of cognitive biases which we are subject to. The positive side is that these biases allow us to operate at the pace we do, filtering and ditching apparently 'irrelevant' information so that we can spend more time on more 'important' information and actions. The negative side is that sometimes that filtering process and the constant use of assumptions means we miss critical information and we end up with the wrong outcome. Most of the time the assumptions we use are valid because we have developed them over a period and we have a natural feedback process - learning from failure. However, divers aren't too good at looking at the reasons behind the outcomes we have, often attributing it to skill when in fact it was luck that an adverse event didn't happen.

Buster Benson undertook an analysis of the 175 cognitive biases listed in *Wikipedia* and built a schema[8] which categorised them into four main groups or problems.

Problem 1: Too much information. There is just too much information in the world, we have no choice but to filter almost all of it out. Our brain uses a few simple tricks to pick out the bits of information that are most likely going to be useful in some way.

Problem 2: Not enough meaning. The world is very confusing, and we end up only seeing a tiny sliver of it, but we need to make some sense of it in order to survive. Once the reduced stream of information comes in, we connect the dots, fill in the gaps with stuff we already think we know, and update our mental models of the world.

Problem 3: Need to act fast. We're constrained by time and information, and yet we can't let that paralyse us. Without the ability to act fast in the face of uncertainty, we surely would have

[8] https://betterhumans.coach.me/cognitive-bias-cheat-sheet-55a472476b18

perished as a species long ago. With every piece of new information, we need to do our best to assess our ability to affect the situation, apply it to decisions, simulate the future to predict what might happen next, and otherwise act on our new insight.

Problem 4: What should we remember? There's too much information in the universe. We can only afford to keep around the bits that are most likely to prove useful in the future. We need to make constant bets and trade-offs around what we try to remember and what we forget. For example, we prefer generalisations over specifics because they take up less space. When there are lots of irreducible details, we pick out a few standout items to save and discard the rest. What we save here is what is most likely to inform our filters related to problem 1's information overload, as well as inform what comes to mind during the processes mentioned in problem 2 around filling in incomplete information. It's all self-reinforcing.

The way we can prevent biases and heuristics catching us out is to recognise when critical situations are likely to occur and to raise our game when it comes to monitoring the situation; the WITH model in Chapter 11 covers this in more detail. A correctly formatted brief will help with decision-making and increase situational awareness e.g. by briefing a minimum volume/pressure of gas which we want to end the dive, and a rough time we think it will happen, we can start to raise our awareness as we get closer to that time or pressure. However, it requires us to understand the rate at which our breathing gas pressure drops while at depth. The brief might also include something which covers previous experience which might shape or frame decision-making.

The following narrative from Clare Pooley describes a cave diving incident in which such knowledge could have reduced the likelihood of the stresses faced by the team in a sustained zero-vis exit from a cave, and at the same time, there was a recognition within the team that something wasn't quite right and so they ended the dive early. As with many incidents and near-misses, there are numerous positive and negative actions which take place and we need to make sure we don't just focus on the negatives, but also look at the positives. For example, how many consider the 'obvious' major contingency (failed scooter/Diver Propulsion Vehicle (DPV)) but it might not be the most critical event that you could face on a DPV cave dive. Using a DPV in a cave isn't just about going faster and further, there are some fairly major implications that need to be considered when it comes to failures.

Case Study: Blind Exit with Scooters

It was a great day in Florida when I returned to dive a cave I had dived several times before. This time I was returning with my buddy, who had accompanied me on previous dives, and two other very competent divers, one of whom I had done a lot of quite advanced cave diving with and the other who I had dived with a few times – although not in a cave. They had been doing some diving together that week. They had not dived this cave before.

On previous dives, we had reached the limit of swimming. This time, we had brought scooters to see some new caves. The plan was to enter in two teams, scooter for a predetermined distance and then drop the scooters and swim until gas limits were reached. We looked at the maps and worked out that this should get us to the end of the cave.

We had to take a boat to the cave and, on tying it up at the dock, I put on my drysuit only to break the neck seal. I had a spare, back at the house, and rather than force me to miss the dive everyone agreed to return with me to get it. Leaving two diving and taking the boat away was not a safe option. This put our timing out by about 45 minutes and so, having been delayed, we entered as a four rather than as two pairs with a period of time between us.

Two of the borrowed scooters were very poorly weighted, sinking like a stone when let go, but the divers using them felt that they would be able to cope.

I led us in, my buddy behind me, then the other pair with the most experienced bringing up the rear. The first 20-30 minutes was familiar cave and it felt a good dive with the struggles on the surface forgotten. The new (to me) cave was duly reached but there was time on the trigger remaining, so I pressed on. The cave became a different shape, low and wide with the line tucked in quite tight on the right, quite close to the floor. For those who do not cave dive, I should explain that divers do not hold the line when cave diving but should remain close to it and aware of where it is at all times, so that it can be reached should light or visibility suddenly fail.

We had perhaps four or five minutes left on the scooters when I saw a signal from behind. The diver right at the back was signalling a scooter drop. I was slightly surprised by this – but more surprised that when I looked back at him, the visibility was markedly worse behind us than in front. A team of four with propellers on scooters raising small amounts of silt through prop wash in the low cave and bubbles from an open circuit dive hitting silt on the ceiling was creating far more *disturbance in the cave than I had seen before. I realised that his suggestion that we drop the scooters early was a great one.*

We dropped the scooters and the stage bottles we had been using and pressed on into the cave. The cave soon opened up again and we went on to have a great dive. We did not make the end of the line, but all were content to turn when we did. It later transpired that the dive was not thumbed on a gas limit being reached but a comfort level – the diver, right at the back, felt we had gone far enough.

The order of the team was reversed on the way out – I was now last and surprised to see, even in the bigger cave, how much our bubbles had disturbed from the ceiling. This part of the cave was not dived much, and sediment was falling from the ceiling with our exhaust bubbles. Four divers going in and now four divers coming out was affecting visibility and I soon couldn't see the lead diver at all.

We made reasonable progress until we returned to our stage bottles and scooters. I picked mine up and waited for the signal to set off. As each diver passed through the cave for a second time more and more particulate were falling from the ceiling and more silt was being sucked up by the props on the scooters. As the narrow part of the cave approached, we were forced closer to the bottom and then the inevitable happened – a diver ahead misjudged things slightly and hit the bottom. The silt came up, went through the prop of his scooter, and the poor visibility went to zero.

I knew that the line was down low, close to the floor and now on my left. I had my hand on it in seconds – as did other members of the team ahead of me (although I did not know this at the time). Thus, one hand on the line, the other hand holding my scooter as high as possible to avoid contact with the cave floor, I started to head out.

After a short time, I was surprised that the visibility was not improving. Normally, after an impact, divers will soon emerge from a cloud and be able to make progress again. What was happening was that the heavy scooters my buddies had were dragging in the cave and taking the problem with us. Smacking my manifold into the ceiling for the umpteenth time, I started to do the maths and it was not good. At best we were exiting at about 1/20th of the pace we entered the cave. Whilst we had extremely good gas reserves planned, no gas planning would allow for an exit 20 times slower than entry.

There were no options but to press on. Slide one hand along the line, another hand in front of the face to ensure I avoided the sharp rock on the ceiling. Occasionally a hand on a buddy's arm where the cave permitted. I'd been in zero viz numerous times before and the team was functioning well, but this was a different issue due to the gas volumes available, travel times and the fact that we were continuing to destroy the viz by our very presence in the cave.

Eventually (around 20 minutes) the cave opened up following a restriction and the line was away from the floor. The visibility immediately improved sufficiently to allow us to swim and then, after a few more minutes to scooter.

Exiting with 80-bar in a twin set, which was just in reserve, also proved to me the value of conservative gas reserves – particularly on scooter dives where there can be such a difference in travel times. Most scooter gas plans are made on the basis that the scooter may fail and you may have to tow or swim. Going from scootering to touch contact on exit is such a large difference that I am not sure any gas plan would have allowed us to exit the whole distance in this way. Our buddy's call to drop the scooters early due to the conditions he could see from the back of the team was a very good call – and saved us probably another 20 or so minutes.

For me it was one of those "grass is greener, sky is bluer dives". It taught me a number of things but probably the biggest is that problems can sometimes be building behind you and to always have an eye on your exit.

System 1 and System 2

Two researchers, Kahneman and Tversky, developed a theory which described decision-making under the context of behavioural economics. In 2002, Kahneman won the Nobel prize for economics for their work, unfortunately Tverskey had died a few years prior and so didn't see the results of their work.

System 1 is about fast, intuitive and automatic decision-making based on biases, heuristics and mental shortcuts. There is very little control involved and most of the time the answers are good or rather they are 'good enough'. System 1 is used most of the time we make decisions and so the 'choices' made aren't really choices. System 2 is the more logical and methodical way of processing information. While you might think that System 2 would help us make more effective decisions, it has a couple of downsides. Firstly, it takes considerable time to collect the data, process it so its relevance and importance can be determined and then a plan of action created before a choice is made, the action is executed, and feedback observed. Time that is often not available in modern life, and normally not available when underwater with a finite gas source either. Secondly, System 2 requires mental energy to process. Humans are very efficient creatures and anything we can do to reduce mental effort is a good thing. We could say we are lazy or efficient, depending on whether you are positive or critical! Crucially, System 2 needs to be kicked in when there is a decision which can't be easily reversed.

This is why we often describe those involved in accidents, incidents or near-misses as being complacent because they were doing something without thinking about it. The dictionary definition of complacency[9] is *"self-satisfaction especially when accompanied by unawareness of actual dangers or deficiencies".* However, that doesn't necessarily help us improve our decision-making processes leading to improved diving safety.

The way I explain the concept of complacency to get people thinking about the process and not just the outcome, is to say that if we do something which uses mental shortcuts and we don't have an adverse event, that would be called efficiency by many people. Whereas if they do the same actions, informed by the same previous experiences, and they have an adverse event because something has changed, then complacency is normally attributed to the activity! Erik Hollnagel coined the term 'Efficiency Thoroughness Trade-Off' whereby there is a constant balancing act between quality and time/resources and we only find out the balance is wrong! There is so much on this topic, that Erik wrote a whole book about it![10]

Some might argue that complacency and normalisation of deviance are the same, but I don't believe they are. Normalisation of deviance involves a gradual drift from 'safety' with new baselines being set over a period of time, which are considered to be 'safe'.

The conflict we face about right and wrong actions is because we are subject to two biases called outcome bias and hindsight bias, and they massively impact our future decision-making processes. If nothing went wrong, then it must have been okay! What needs to happen to correct this mindset is to have a debrief which doesn't just look at outcomes, but also the process. In

[9] https://www.merriam-webster.com/dictionary/complacency
[10] https://www.amazon.co.uk/ETTO-Principle-Efficiency-Thoroughness-Trade-Off/dp/0754676781

effect, look at how we got to where we are. Four high-level questions I teach my students to use during my human factors/non-technical skills classes to help facilitate this learning are:

- What did I do well? Why?
- What do I need to improve on and how am I going to fix that?
- What did the team do well? Why?
- What does the team need to do to improve and how are we going to fix that?

It is essential that those questions are answered in specific manner rather than general terms. e.g.

"Team communications was good." - Bad.

"The way John asked an open question to see how much we understood the brief and what we were going to do at the bottom of the shot was great. It picked up the fact that Billy was supposed to partially inflate the lift bag and he wasn't aware of that fact." – Good.

More will be covered in Chapter 9 in the *Teamwork* section on briefs and debriefs as a way of improving decision-making.

Naturalistic Decision Making

The work which Kahneman and Tversky undertook was mainly done in controlled scenarios using college students, in circumstances where as many of the external factors and drivers were removed from our normal decision-making processes e.g. running late, limited money, external peer pressure/social conformance, experience outside the direct task at hand and so on. The idea being that by isolating external factors, the biases and behaviours could be identified. This was ground-breaking research which is why they won the Noble prize, but it doesn't easily relate to much of the real world where numerous factors, pressures and drivers are present. Drivers and pressures which skew our decision-making processes and outcomes. Cue the work by Gary Klein and his associates which developed a concept called *Naturalistic Decision Making* (NDM)[11].

The theory they put together was that decisions weren't made in a logical, systematic manner where options were weighed up and rated, but rather they were based on observations of cues and patterns and how these compared with previous experiences, mental models and expectations. The closest 'fit' would be chosen (subconsciously) and the actions associated with

[11] Klein, G., 2008. Naturalistic Decision Making. *Human Factors*, 50 (3), 456–460

that ‘fit’ executed. This is another example of where mental models come in and why their accuracy to reality is important.

What became apparent from their research was that novices had a limited set of experiences and mental models to compare their current reality against. As such, it took them longer to determine and then choose what was an important cue or clue to help with the decision-making process. Furthermore, if they didn’t have a close fit, they would try the best they could to make something fit. This ties in with the work from Rasmussen who described knowledge-based decision-making where the error rates were in the order 1:2 - 1:10. Experts on the other hand, could observe a scene or situation, pick out the most important elements, quickly make a decision based on the fewer elements, execute the task and have a better idea of what ‘success’ looked like. Experts were also quicker to stop a course of action when it wasn’t going to plan and then restart their analysis and execution process. Captain Sullenburger captured this nicely with his quote:

“*For 42 years I’ve been making small regular deposits in this bank of experience, education, and training. On January 15 the balance was sufficient, so I could make a very large withdrawal*.”[12]

Klein’s work was originally based on firefighters and military commanders and how they made decisions in the ‘heat of the moment’. Ironically, when first questioned, the leaders said that they hadn’t ‘made’ decisions but just did what needed to be done.

Using more directed questioning, it was apparent that the most effective fire chiefs were able to determine cues and clues from the way the scene was developing, from the colour of the smoke, the wind direction, the location of the fire, the building materials etc. This gave them some patterns to match against their previous experiences and execute an ‘action script’. What was interesting was that the experience could be passed around the team through the use of effective and targeted debriefs after each fire was fought. These were lessons both identified and learned, and therefore could be shared within the team for the next fire. By having a common goal for improving the firefighting performance of the team because, lives depended on it, the teams knew it was advantageous to talk about what worked and why, and what didn’t work and what they

[12] https://www.telegraph.co.uk/films/sully/a-real-heros-story/

would do differently next time. Iterative learning within the team accelerated the individual learning processes and improved their own and the team's performance.

In the context of diving, this could be an 'expert' diver observing the current pick up and change direction which would indicate that they would need to turn back sooner, rather than follow the initial plan which was based on either gas consumption/remaining or time duration. A novice is more likely to follow the plan unless they encountered such situations before. Contingency planning does help provide some 'fat' in the system but doesn't help with making a sound decision, it only mitigates a poor (in hindsight) decision. The rear diver in Clare's narrative above highlights how an 'expert' made a very sound call because they could 'project' what was likely to happen if they didn't drop the scooters there.

Using Checklists to Improve Decision-making in Critical Circumstances.

System 1 behaviours are there to provide mental shortcuts in well-practiced situations and save time. However, sometimes we need to intentionally slow people down, so they don't assume something is in place. That are what checklists do. They intentionally create System 2 behaviour when it is critical that something is done correctly first time around.

Checklists, specifically written checklists, don't have a great reputation in diving, especially technical diving. This may have come from the past where divers were expected to know everything from memory and be self-sufficient. That same mindset of perfectionism has been shown to be present in healthcare with surgeons. The surgeon behind the *World Health Organisation Safe Surgical Checklist*, Atul Gawande, is quoted as saying "*that when questioned, more than 90% of surgeons, if they were a patient, wanted their surgical team to use a checklist but 24% actually used a checklist on every occasion.* [13]"

However, checklists are not the panacea they are often made out to be. They need to be effectively designed, they need to fit into the operational environment in which they are going to be used (too big, too bulky, on an iPhone/Android phone) and they need to be based on the technical competence for the average user. They should not be used as a liability limiting tool which can be used to say the diver ticked the box but didn't execute the task, therefore it was their fault the event happened in the way it did. A quote which often comes up is from *Rebreather*

[13] https://www.bbc.co.uk/programmes/b00729d9/episodes/player, Reith Lectures, December 2014.

Forum 3 where David Concannon said that in all the rebreather fatalities he has investigated, he has not found a checklist on the diver or in their kit bag. My counter to that is that every aircraft which crashes will have a checklist present. The presence of a checklist won't prevent every fatality, but it will reduce the likelihood of one occurring massively, as long as it relates to the configuration and operation of the equipment and the fatality is not health related.

My view is that for critical checks, there should be one common checklist across ALL diving organisations, be that a verbal checklist or a written one. The reason for this is because consistency of repeated actions reinforces what the action should be and if something is missed, then it is more obvious, both from another's perspective and also from self-awareness. If one agency teaches ABC (Air, Buoyancy, Clips), another teaches BWRAF (Buoyancy, Weights, Releases, Air, Fins), another GUE EDGE (Goal, Unified Team, Equipment match, Exposure, Decompression, Gases, Environment) then what check is done when mixed teams or diving operations take place? The challenge is that each of the agencies wants to have their own brand when it comes to products…

Guidance for checklist design.

My experience, and that of others, is that when going through CCR training instructors advise their students to develop their own checklist based on the manufacturer's manual. While this limits liability and might help develop an understanding of the reasons behind the items in their own checklist, it does not help with accountability within the team because I cannot see if you have missed something. If your checks are different to mine, I don't know if you've missed a step or it is intentionally not there. However, I have been asked on a number of occasions to give some guidance on how to write a checklist.

- Checklists should be no more than 7 lines long. If there are more than 7 items, then create a new checklist for a different phase.
- The words in each line should be mental prompts and not full sentences.
- The checklist needs to be accessible at all times it will be needed.
- Verbal checklists for solo divers WILL fail. Verbal checklists in a team are less likely to fail.

- Checklists need to be designed within the time and environment they are going to be used. By that I mean, having a full page of text for a boat final check means it is likely to be covered than a few critical items.
- Only operationally relevant, timeline and detail, should be included. A pre-jump check should not have 'bubble check' after entering the water!

Crucially, there is a specific mindset required to use a checklist. That mindset says, "I don't know when I will fail to do a memory check, but I will, so I will use this checklist.". If you are interested in learning more about checklists and checklist design, consider reading *The Checklist Manifesto* by Atul Gawande.

Case Study: Thumbing the Dive isn't Easy, Even as an Instructor

The following narrative from Andy Davis, an advanced trimix instructor based in the Philippines, and from his student show how having two different perspectives can be beneficial when understanding the 'flawed' decisions which took place. 'Flawed' is in inverted commas because hindsight makes it so easy to determine why things went wrong! As with all of the case studies in the book, look at them not with the benefit of hindsight, but rather what cues and clues would you look for to prevent such an event happening to you and how would you overcome the mental biases we all have to complete a task which is important to us. Decisions made in the armchair are nowhere near as complex and difficult as those which need to be taken when all the drivers and pressures are placed upon us in the activity.

Earlier this year I conducted a 72-meter, open-circuit trimix dive off the coast of the North-West Philippines. It's a dive that I'd done many times previously when conducting trimix qualification courses.

The dive is onto the wreckage of a US Navy AJ-2 'Savage' carrier-based nuclear bomber. It's a small dive site, with only the wreckage standing alone on an otherwise desolate sandy bottom. We typically only dive the site in very fine weather, as that stretch of coastline is very unprotected during the monsoon season storms, and the available dive boats are relatively lightweight local boats and unable to handle anything beyond marginal sea conditions.

My student for this dive was a fellow that I'd mentored extensively over several years and we had established a close friendship. He worked in several different countries and had very tight *windows in which to accomplish training dives. On his previous trip to Subic Bay, we'd had to abort our attempt to dive that site because of high seas which had involved hanging around on the dive boat all day and hoping for the wind to calm. It didn't.*

I knew the student was very eager to dive that particular wreck and also complete his trimix qualification. He didn't put me under any direct pressure, but I knew we had very few opportunities left to dive that site before the monsoon season arrived and we'd be unable to get outside the bay for another six or seven months.

Everything went according to plan in the preparation for the dive. We had cylinders of deco and back-gas, analysed and marked, from our previous attempt ready to go. Our kit was already packed in crates for the boat. We'd spent hours planning, assessing and agreeing the dive parameters, deco schedule, contingencies and risk mitigation options. The dive boat departed shortly after dawn so that we could avoid the stronger afternoon winds typical for the late-spring season.

When we arrived at the grid-reference for the site, there was a long rolling swell of about 1-1.5 metres and a moderate surface drift. The boat ladder was smashing up and down in the water as waves passed. It would make water entry and exit more problematic in sidemount configuration, but this was something we could effectively plan around before we started.

The boat crew deployed the shotline and marker accurately on the GPS mark. I had confidence in their mark and ability to deploy accurately based on my previous experience with them. The shotline was a lightweight affair, with a 6-kilogram weight under a large plastic buoy, linked by a set length of 8mm nylon-braided rope. I would personally have chosen something more substantial, but we were chartering from another dive operation and this was their standard routine.

The first trio of divers entered the water and descended. They were diving CCR and DPV with an intention to conduct a long bottom time in preparation for an upcoming expedition. We allowed 45-minutes before my student and I kitted up and entered the water. This should ensure we'd pass the first group as they ascended through their deco schedule; providing some extra measure of mutual support between teams.

As we descended through the blue water to our target depth, it became apparent that the other group hadn't returned up the shotline. When we reached the bottom there was no wreck to *be seen. However, it immediately became apparent that the shotline weight had dragged itself across the sea floor.*

The combination of a large buoy and moderate swell was lifting and dragging the meagre 6kg weight cross the sand. We had maybe fifteen metres of visibility and the channel in the sand caused by the dragging weight extended far beyond eyesight. If the aircraft wreck was anywhere nearby, then we'd see indications of it, especially the large schools of fish that typically inhabited the wreck, or smaller items of debris. None were apparent.

At this time, we had to make a decision on the best course of action. The previously discussed contingency was to deploy a 30-metre finger spool and conduct a circular search around the base of the shotline. If that didn't achieve success, we'd abort the dive and surface according to our planned schedule.

I was clear-headed at depth, as we'd used trimix to keep our narcotic depth under 30-metres. Nonetheless, I began to second-guess our planned contingency. I was acutely aware of the cost of the dive for my student, coupled with his previous disappointment and our limited opportunity to complete the dive again for the remainder of the year. The sand-trail indicating the direction that the shotline had been dragged seemed to make a reel search unnecessary. However, at the same time, I was disinclined to swim away from the line without an assured method of return.

I made an atypical decision to manually lift the shot-weight and swim back along the drag-channel pulling the entire line assembly and buoy behind me. My rationale was that it couldn't be too far, and it would be simpler than having to recover, or cut-away a finger spool when the bottom time got short.

I signalled my intention to my student and we set off along the drag channel. I had inflated my sidemount BCD to compensate for the 6kg of weight I was carrying. Nonetheless, I swiftly became aware that dragging the line involved considerable exertion. We swam further and further along the drag channel, but the wreck failed to appear.

After covering perhaps 150 metres, I had to signal my student to assist me dragging the line. The distance was far longer than I expected and my level of exertion much higher than I'd typically tolerate on a technical dive.

It didn't occur to me to abort or re-consider my plan at this stage. I had become very task-fixated on finding the aircraft wreckage; almost desperate not to disappoint my student. We *continued together, dragging the shotline, for perhaps another 100 metres before I really became aware that I was suffering from some CO2 retention. My head felt like it was spinning, my breath was short and my chest felt compressed.*

I hadn't fully considered the level of exertion that I was subjecting myself to and had over-estimated the capacity for trimix to offset and alleviate gas density / respiration issues. A 30-meter narcotic depth was not nearly sufficient to compensate for dragging a long shotline for such a distance at that depth and against the surface tow on the buoy itself.

We still had a third of our planned bottom time remaining, but an instinctive warning had illuminated inside my now CO2-fuddled mind. I dropped the shot-weight, being careful to dump the surplus buoyancy from my BCD in the process. We took another look around and could only see the drag-channel stretching further into the distance. A team gas-check confirmed that we were over our estimated Respiratory Minute Volume (RMV) rates and would be into our reserves if we persisted any longer at depth.

We signalled to ascend and recovered up the shotline, completing our scheduled decompression without further incident – although it wasn't until well through our deeper and middle 50% stops before I felt fully recovered from the CO2 hit.

Once back on the boat, we took a GPS mark for the actual location of the shotline. It measured over 450 metres away from the actual mark where it was dropped. Even accounting for us dragging the shot perhaps 250 metres during the dive, it was obvious that we never came close to reaching the wreck.

The first trio of CCR divers surfaced over thirty minutes after us. They'd abandoned the shotline but used DPVs to follow the drag trail to the wreck. Even with that propulsion, they'd had relatively little time on the wreck, before conducting a blue-water drifting deco ascent; eventually surfacing nearly two kilometres from where they'd entered on the shotline.

The same event is recalled by the student, Peter Stubley.

I've been diving with Andy for four years when he was brought in to teach the Tec 45 class, I'd booked with a Subic Bay operator I'd been using for some time. With our shared background, we got on well, and I started booking further courses directly with Andy. We've dived together about thirty times now. I had previously taken a week off work to complete my Trimix course, but I was sick during the mid-week, and was only able to complete the Tec Trimix 65 course, instead of the *full Trimix as planned. We had however hoped to dive the AJ-2 'Savage' as the first dive towards the next course. This was to be a personal goal of mine, ever since seeing the drawing on the dive operator's white-board when I first dived Subic Bay. This first attempt at the 'Savage' was blown out due to adverse weather, and the day on the boat waiting for the weather to calm down only added to the disappointment.*

I was able to make the trip four weeks later for another attempt on the AJ-2. The gasses were still in the shop, but Andy and I arranged to meet the previous afternoon to test the gases, and make sure all was well with our kit, as we were again planning an early start to get the best of the weather. After testing the gases, we relaxed over snacks in the resort bar, and discussion turned to CO2 narcosis. I was especially concerned about this, as I am not the fittest diver, and my job didn't allow for a regular fitness regime. We'd discussed not spending too long on the surface, as the 17% Oxygen content in our mix wouldn't help relieve the Oxygen debt of any exertion incurred getting to the buoy.

The descent down the shotline in blue water is for me, one of the best aspects of ocean diving. The anticipation of what I would find at the bottom of the line, was increased that day, as there should have been a nuclear bomber at the end of the line. When we reached the bottom, and it was only sand as far as we could see, there was a tinge of disappointment. However, I'd learned to dive with a university club in the UK in the early 90s when GPS was in its infancy, so was quite used to diving 'HMS Nearby'. When I saw the drag marks of the shot in the sand going into the distance, but no sign of the 'shoals of fish directly above the wreck', I knew that the chance of finding the 'Savage' would be slim. The surface conditions and the small weight could have dragged the shot a long way from the wreck in the time we waited to drop in. I was half-expecting Andy to produce a reel from nowhere, as he has done before, so was surprised when he signalled to me, then picked up the shotline and started carrying it in the direction of the drag-marks. I was worried that this was sub-optimal, but I wasn't going to argue with Andy underwater, especially as I wanted to see the 'Savage'. During the time we were carrying the shot, I was calculating how long we'd have on the plane before we'd need to start our ascent, the 'time on plane' eventually decreased, such, that I'd figured even if we did find it, we'd have no time to look at it.

When Andy dropped the shotline, I knew that I wouldn't see the plane this dive. This was confirmed when almost immediately after, he thumbed the dive. It was at this point when we *checked our gases that I realised I had not swapped over my side-mount regulators, and that I had breathed way more of my left tank than my right tank. This caused me a fair amount of anxiety as I knew I'd be in a poor position to support Andy if he needed any of my reserve gas after all his effort carrying the shot. His RMV was lower than me, but I hadn't done half the work he had. I was much happier when we switched to our 50% mix, as we had a lot of reserve, and it was during those shallower stops that I started to calculate how much I'd spent to see some sand. The relief was that it only cost me money for gas, and nothing more precious.*

Summary

Decision-making isn't as simple as we think it is. We filter, discard and ignore significant amounts of information and data because we don't think they are relevant. We take numerous mental short-cuts based on this filtered information. Most of the time the decisions we make are 'good enough' for the situations we are in. However, in a few occasions, it doesn't work out very well and someone gets scared, injured or killed. If we can understand the strengths and weaknesses of our decision-making processes, then we are more likely to make more effective decisions. We shouldn't just focus on the outcomes, but rather look at the processes we used and the information we perceived to help inform future decisions.

There are tools which we can use to improve decision-making: checklists, briefs and debriefs. However, checklists are not a panacea. They need to be well designed and not just deployed as a liability limiting exercise for a manufacturer or training agency. They need to be used with the correct mindset - the mindset that says "I am fallible. I WILL make a mistake at some point. Slowing down and checking critical configurations is one way to reduce the likelihood of a fatality."

Finally, when things are going to plan, and you are using skills and rules-based decision-making processes, it doesn't really matter that you don't understand the 'why' behind the activity you are doing. However, as soon as you diverge from the plan, you are into knowledge-based decision-making/performance territory and the likelihood of an error goes up massively.

Answers to the Cognitive Reflection Test:

- A bat and ball cost $1.10. The bat costs one dollar more than the ball. How much does the ball cost? **The ball costs $0.05**

- If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? 100 minutes OR 5 minutes? **5 minutes.**
- In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? 24 days OR 47 days? **47 days.**

The Book

The full book will be released in March 2019. More details on the 'The Human Diver' Facebook group https://www.facebook.com/groups/184882365201810/

Chapter Synopses

Chapter 1: The Role of Human Factors and Non-Technical Skills in High Performing Teams

Safety is boring! That's why this book doesn't focus on safety, it focusses on the skills and mindset required to be a high-performing diving team, individual diver or instructor/instructor trainer. This chapter identifies what non-technical skills mean in the context of diving and why they are so important, using a number of examples of dives where things didn't go to plan, but also how the application of the skills can create exciting and memorable dives, for the right reasons and not the wrong ones!

Chapter 2: Systems Thinking: The whole is greater than the sum of the parts

Systems thinking has been shown to be the most effective way of improving performance and safety. This is because while it is possible to improve specific components or people within a system, unless you look at their interactions with other people, equipment and the environment, you cannot make an improvement in the performance of the system. In diving, there are numerous systems in place: a rebreather, diver, instructor, social and physical environment all make up a system. You can manufacture a rebreather which passes the required standards, but that doesn't mean that it will be safe to use as a system unless you take into account the components of the system.

This chapter will give you an overview of systems thinking and why it is essential to consider it if you want to improve your performance, your safety and the safety of others.

Chapter 3: 'Human Error' and why it isn't that simple

Human error is a term often used as a 'catch-all' but has limited value when it comes to learning to improve. In the 70s & 80s, it was stated that 80% of aviation accidents were caused by 'human error'. Since the 1990s it has been recognised that this attribution is flawed because 'human error' is normal and a common term, which does not help learning from specifics. Human error as a term is traditionally broken down into the following categories: slips & lapses, mistakes and violations. Understanding what each of these means is essential if you want to prevent sub-optimal performance. However, it is not normally possible to classify whether an event was an error or a violation until after the event and we understand the context of the decision-making and execution of skills.

This chapter will provide you with a summary of 'human error', error producing conditions and why we need to search for the 'rich-context' stories if we want to improve.

Chapter 4: Risk Management or Gambling your life away

Much of diving is about risk management but divers don't realise this because of the way in which the sport is portrayed, the suppression of diving incident and accident information and the often adversarial and confrontational nature of near-miss discussions within the diving community when 'stupid' mistakes are made. Risk is a relative concept based on an acceptable level of safety and therefore it is difficult to define 'safe' in a sport which has an inherent risk of death due to the environment in which it takes place. Risk management often talks of 1:x as a risk factor. In diving, the outcome is either 1 (alive) or 0 (dead), you cannot be 1:200 000th dead. However, if we keep having 'ones' without understanding how close we were to the edge, at some point we will step over it and end with a 'zero'.

This chapter will focus on risk, what it is, how we can manage it and the biases we face when it comes to making risk decisions in a dynamic environment. The aim isn't to scare divers, but rather to give them an indication as to how far we can drift and still think we are being safe.

Chapter 5: Just Culture and Psychological Safety

Aviation is without doubt one of the safest industries out there and one of the key reasons, notwithstanding the legislature and enforced standards, is because there is a recognition that failure is normal and that the only way to really identify the failures is to talk about them in an open, frank and non-judgemental way. An individual might be the last person to 'touch it', but once a context rich story has been told because of the presence of a *Just Culture*, it is much easier to see where the failure happened and address the system and not the person. The 'bad apple' theory has been discredited in the literature and does nothing to improve safety. Consistent failures at the 'sharp end' are indicative of a systemic problem, not an individual one.

A *Just Culture* is defined as, "a culture in which front-line operators or other persons are not punished for actions, omissions or decisions taken by them that are commensurate with their experience and training, but in which gross negligence, wilful violations and destructive acts are not tolerated”.

This chapter will highlight that without a *Just Culture* in place, learning is limited, and the same accidents/incidents will continue to occur with the individual divers often being blamed for the failure rather than systemic factors. A *Just Culture* facilitates reporting and learning from adverse events leading to improved safety, whereas blame is the enemy of safety with incomplete stories told, leading to poor incident analyses and sub-optimal behaviours when it comes to hiding near-misses.

Chapter 6: Decision-making

Decision-making has been defined as the process of reaching a judgement or choosing an option to meet the needs of a given situation. It can be broken down into the following main areas: understanding the situation at hand/defining the problem, determining a potential course of action or the option(s) available based on the information immediately at hand, selecting and executing that option and then undertaking some form of review process to determine if the decision was effective in terms of the goals set.

This chapter will describe the different decision-making models and processes we use (Skills/Rules/Knowledge, System 1/System 2, Naturalistic Decision-Making, Biases & Heuristics, Choice-based and Creative) their strengths and weaknesses, how to overcome some of the cognitive limitations we have through the use of checklists, and ultimately give you the skills to make more effective decisions both topside during planning, but also underwater while on the dive.

Chapter 7: Situational Awareness

Situational awareness is often talked about in diver training but there isn't much detail about how it is developed and more importantly what can cause it to be 'lost'. Situational awareness is the concept by which we perceive data through our senses, process it so that we understand the here and now, and then using mental models of reality based on previous experiences, create a future model of what might happen. Simplified as What? So What? Now What?

Research has shown that it is the perception system that is weak when it comes to effective decision-making, rather than effective perception and then poor decisions. Consequently, we need to understand that situational awareness is the ability to focus on what is important and / or relevant at that time while being conscious of, and taking into account, the limitations of focussed attention.

This chapter will describe how the body/brain perceives information, the working memory and its associated strengths/weaknesses, before moving on to how your individual and team situational awareness can be improved in the context of diving.

Chapter 8: Communications

If only we could solve communications problems, then we wouldn't have any confusion or conflict! Communications sits in the middle of the model of non-technical skills and is crucial to high performance. Understanding the barriers and enablers to effective communication is essential if we are to improve performance and reduce error. Despite its importance, very little is taught during diving classes about how to undertake effective communications, how to be more assertive when there is a need to speak up and what makes an effective brief and debrief.

This chapter will focus on the different models of communication, how to decide which one to use and how to increase the likelihood of effective communication taking place through the use of different questioning techniques, briefs and debriefs.

Chapter 9: Teamwork and Teaming

A team is not a group of people who work together, rather a team is a group who trust each other, and creating trust is a challenge in a peer-peer social environment and even harder without a clear leadership role being present. Teamwork is the core to high performance because teams can achieve far more than just looking at the sum of its individual parts. However, teams don't just happen, they take time to develop and they all go through the same development process with conflict and frustration eventually leading to things 'just happening' when there is role clarity, effective communications and the need and want to hold each other accountable.

Teaming is a term which describes the need to be able to operate in teams which are fluid in nature in terms of composition due to the nature of the task at hand. It is different to teamwork which is the output. Teaming has been recognised as an essential trait for high-performance teams who do not have a fixed constitution.

This chapter will focus on how to develop effective and high-performance dive teams using knowledge and understanding from the military, aviation and healthcare domains. It will also look at why teams fail and what can be done to address that. Fundamentally, effective teams understand the difference between teamwork and taskwork and develop their skills to meet both requirements.

Chapter 10: Leadership and Followership

Most groups have some form of leadership present, be that formal or informal. Leaders can easily set the tone, positively or negatively, within the group and effective followers will provide support. However, destructive goal pursuit, where the goal is more important than the safety and well-being of the team-members, combined with poor leadership, can easily lead to accidents or incidents. This is especially true with beginners who do not have the assertion skills and don't recognise the authority gradient which is present.

This chapter will focus on leadership and leadership styles in the context of diving and how knowledge of these can improve diving enjoyment, goal attainment and instructional abilities. Leaders make or break a team and it is they who create and maintain an environment in which others can speak up and challenge others within the team or dive business. The chapter will also cover the topic of followership and why it is so important in a recreational activity where decisions need to be done considering a team and not just individuals.

Chapter 11: Performance Shaping Factors

You can have the best technical skills in the world and be able to apply a high level of technical and non-technical skills, but if you don't understand the impact of stress and fatigue on your own and others' performance, then you are destined to failure. Both stress and fatigue lead to miscommunication, narrowing of focus, ineffective decisions due to being more risk-seeking, incorrect application of leadership style, amongst many other things, all leading to reduced performance.

This chapter will provide divers, especially supervisors, an overview of how stress and fatigue shape human performance and what can be done to manage these factors thereby improving diving safety. Furthermore, linking with the human error chapter, error producing conditions will be covered in more detail here.

Chapter 12: Living with Failure.

Failure is everywhere. However, we cannot innovate or improve if we don’t fail. Despite this, failure has been given an incredibly negative attribution by most parts of modern society, normally because something has been lost or didn’t reach fruition, be that a goal, money or a tangible product. What if we turned it around so that learning from failure was seen as the key to improvement? What if we looked at the failed processes and unsuccessful outcomes as lessons and opportunities to learn and not just identify where the failures happened.

This chapter will focus on learning from experience and will give you specific tools whereby you can apply 20:20 hindsight before a major trip or expedition or use learning reviews to understand what really happened rather than what should have happened. Telling stories about things which didn’t happen doesn’t help learning.

Chapter 13: Bringing it all together

This chapter will summarise the learning points from each of the chapters and provide readers with quick wins on how to apply the contents of this book into their own diving, instruction and leadership.

The Human Diver was set up to provide training, coaching and development for divers of all disciplines and experience levels on how to improve their knowledge, skills and attitudes towards human factors, non-technical skills and just culture. The ultimate aim being to make a definite improvement to diving safety by changing perceptions towards how to create safety, develop a just culture and refine what 'good' looks like.

The training provided is currently in three forms,

- a 2.5-3 hour online eLearning programme which provides an overview of the topic using simple case studies and practical exercises. http://www.thehumandiver.com/p/microclass
- a 10-week webinar series covering the topics in this book in an interactive manner combining theory and discussion along with practical exercises to consolidate the learning. https://www.thehumandiver.com/p/webinars
- a two-day face-to-face class using a unique, computer-based simulation to develop teams and individuals and combining this with case study discussion and more theory. https://www.thehumandiver.com/p/classroom

In 2019, this will expand to include multiple classes, an instructor development programme so others can teach this topic, and also an incident investigation course.

What others have said about the existing programmes

Online programme: *"Honestly, the material is fantastic and the production quality is stellar. I have never seen such a well-presented programme."* Jill Heinerth

Face-to-face programme: *"If you think your team is high performing, take the micro-class and find out how much you don't know you don't know. If you want to make* your team *higher functioning, achieve more, have more fun, take the two-day class. A must for instructors, team divers and leaders of diving projects."* Meredith Tanguay, GUE Cave Instructor, Project Baseline Diving Safety Officer.