Capturing the Stupid Stuff: Using Checklists to Improve Performance in Scientific Diving

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Abstract

Most divers are introduced to the use of checklists during entry-level training for everything from packing dive bags to analyzing their gas. A variety of certification agencies provide their instructors cue-cards as simple memory tools for dive planning, conducting pre-dive briefings, and assuring all required skills are included in various training dives. As scientific divers we may use checklists to verify mission-critical equipment lists, manage complicated procedures, or simply pre-flight a rebreather before a dive. This paper presents some sample checklists for scientific diving, explores why and how they may be used as a tool to improve performance and efficiency, and describes some of the reasons why we often struggle with and even abandon checklist use. Checklists intentionally slow the pace down to reduce System 1 errors; as such, they should be designed to ensure the maximum efficiency is still maintained. Consequently, this paper does not propose to create additional layers of compliance, paperwork, or bureaucracy to our diving, but rather promotes the view that checklists can be valuable tools if implemented effectively and should not displace the human from the system of safe diving.

Keywords: diving safety, human factors, human performance, risk management, safety clutter

Introduction

Suggest the use of checklists to some dive teams and watch them cringe or roll their eyes. Often the response is along the lines of "we are experts who do this every day and don't need a checklist taking valuable time." Yet ask them to choose going into surgery or on a routine flight with or without a checklist in use, the response is overwhelmingly "Checklist, please!" Certainly checklists have been shown to be effective to reduce or mitigate the risk of mishaps in other industry, such as surgery and aviation (Haynes et al. 2009; Helmreich, 2000) and Gawande's (2010) Checklist Manifesto has become a seminal work on the subject, providing guidance in their design and implementation. However, we don't know the extent of use of checklists in scientific diving. A trial investigating the effect of using a pre-dive checklist in recreational diving by Ranapurwala et al. (2016) suggests that the use of a pre-dive checklist prevented 30-40% of mishaps and should become a cornerstone of the scuba diving safety culture. Ranapurwala et al. (2017) further reports that while only 8% of participants used a written checklist, the "routine use of written pre-dive checklists is an effective tool for promoting diving safety." It should be noted that the checklists in this study were far more complex than most divers would use and therefore the real improvements may be less as there is 'friction' when using such checklists, a topic covered later in this paper. While there are significant differences between scientific diving and recreational diving (and indeed between the industries of diving, aviation and surgery) this paper explores the use of checklists through the lens of the similarities and values we do share, and applying the lessons learned. A series of sample checklists are presented with the invitation to the scientific diving community to review, revise, and collaborate on their content with the intent of improving them as tools for use in our programs.

Why Checklists?

Human Error and Human Factors

Many of the authors cited in this paper provide evidence that checklists can help protect us from failures, and this leads us to acknowledge the nature of such failures. Human error is consistently portrayed as the cause of most mishaps, but according to Dekker (2017a), the idea that the system is essentially safe, and the problem is a few unreliable people, is a trap and misconception. Dekker (2017a) presents the view that human error is normal, is influenced by organizations, and that human error is not the cause, but the consequence. Dekker (2017b) admonishes us to look beyond the notion of human error and consider the impact of broader organizational expectations and pressures, such as conflicting goals, productivity, and limited resources. A checklist may indeed protect against certain types of 'human error' but it also may provide a shared understanding of the complexity and dynamic nature of the environment scientific divers work within. It may also help prioritize the appropriate mechanisms that contribute to successful outcomes of both safety and other measures of performance, such as efficiency and data quality.

Complexity and Mindsets

The more complicated a situation is, the more room for error and mistakes to propagate through the system, as such, checklists can be a very useful tool in these cases. Experienced scientific divers may not perceive their work as particularly complicated and may have a mindset that, as professionals, they should know everything from memory. However, the neuroscience of memory shows that it is imperfect and susceptible to distortion and loss (Lacy et al. 2013). Rannapurwala et al. (2017) found "the use of memorized checklists was similar to not using any checklist at all; hence the use of written checklists should be encouraged, instead."

Another mindset that may create reticence toward checklists is a view that they are too rigid, or too simple. Gawande (2010) notes that "The fear people have about the idea of adherence to protocol is rigidity. They imagine mindless automatons, heads down in a checklist, incapable of looking out their windshield and coping with the real world in front of them. But what you find, when a checklist is well made, is exactly the opposite." Alternatively, the humble checklist may seem too simple, too "analog" in our modern world of innovation. It is not shiny new technology delivered with glossy marketing screaming that it is cool and sexy. But that very simplicity can help us capture the stupid stuff we may otherwise miss in the moment. Checklists can help get the "dumb stuff out of the way, the routines your brain shouldn't have to occupy itself with" (Gawande, 2010).

Improving Decision-Making

Checklists may also aid in our decision-making processes, particularly in complex conditions. Lock (2018) notes that about 95% of decisions are made in an automatic subconscious manner and we don't actively think about them, i.e. the 'System 1' sensu Kahneman (2012). During System 1 behaviors, or when undertaking Naturalistic Decision Making (Klein, 1999), the brain is using patterns to match the current situation against mental models from the past, models which only have to be close enough to be a match. When in critical situations where there is no opportunity to reverse the decision, or taking part in activities when the critical outcome is encountered sometime in the future, then slowing down is essential and checklists can help increase the likelihood of a correct decision or configuration. Lock (2018) further suggests that if "we understand how decisions are made, and what we can do to reduce the impact of the way in which our brains take mental shortcuts, then the decisions we make are more likely to be effective which consequently leads to safer diving."

Dekker (2017b) speaks extensively about controlling safety versus managing safety. If we apply this to checklists, they should not be employed as a coercive means of controlling the safety of the team but rather as a tool that may help manage safety and improve performance, leaving space for professional expertise to adapt and make decisions that address the needs of the moment.

Communication

Perhaps the greatest purpose of a checklist is to improve communications among team members. A well-constructed checklist in the hands of an adept team should serve to open communications between team members. Gawande (2010) states "The researchers called it an 'activation phenomenon'. Giving people a chance to say something at the start seemed to activate their sense of participation and responsibility and their willingness to speak up." He also cautioned that "ticking boxes is not the ultimate goal. Embracing a culture of teamwork and discipline is…but also to instill a kind of discipline of higher performance." Catchpole (2015) highlights that "…a checklist reliant on teamwork for success may fail despite all the items being followed, because those team skills were insufficient."

Modes and Types of Checklists

Types of checklists vary widely. Fox (2010), describes task lists for standard procedures (when a detailed list or step by step process is needed), project coordination lists (where multiple people may need to collaborate), and troubleshooting checklists as particularly useful in time-sensitive situations where getting the right diagnosis or outcome is key (e.g., a clear set of instructions for responding to an emergency). Fox (2010) also noted that checklists are sometimes used to reduce emotion in a decision-making process and may reinforce discipline to particular processes.

Checklists can generally be used in one of two modes. The Read-Do mode works something like a recipe, with users reading out the item on the list and completing it before going to the next item. The Do-Confirm mode is a bit more flexible, with some of the checks being completed from memory before consulting the list. This mode usually has pause points built in at common sense points in the checklist, allowing users to pause and confirm the items on the list. The Do-Confirm mode has a potential problem because the user is storing half-complete actions in their working memory, which is susceptible to distractions. To counter this, Japanese train companies started to develop a process called Shisa Kanko or pointing and calling. Figures from the Japanese train system indicate that mistakes have been reduced by 85% and accidents by 30% (Gordenker, 2008).

Features of a Good Checklist

A prime reason why checklists may be rejected concerns the intent behind them. Before constructing a checklist, we need to be clear what the objective or purpose of the list is. What exactly is it meant to do? A checklist that is coercively imposed as a means to control behavior will likely fail. A checklist introduced with a clear philosophy of empowerment of the frontline employee is likely to enjoy greater success and engagement by the users. Many organizations maintain an approach of centralized authority and decision-making power; however, this translates poorly in scientific diving since corporate leaders will rarely have the knowledge or expertise to make the best decisions and are usually not present to do so. Decentralizing, or pushing the power of decision making down the organizational chart gives those in the field (who are closest to the work) room to adapt to the needs of the moment. Here they can make decisions based on their expertise and prior experience. Well-designed checklists should act as a guide to this process, encouraging the emergence of a way of doing things that becomes an organizational culture and habit, not as a prescriptive rule-based point of failure.

It is therefore equally important to state that a checklist should not become a rule-based burden, an additional example of paper safety or cog of bureaucracy. This simply contributes to 'safety clutter' described by Rae et al. (2018) as the accumulation and persistence of 'safety' work that does not contribute to operational safety. Rae et al. (2018) go on to say "when 'safety' rules impose a significant and unnecessary burden on the performance of everyday activities, both work and safety suffer."

Lock (2018) also emphasizes that checklists (Figure 1) need to be well designed, fit into the environment they will be used in, and "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."

Figure 1. Checklists need to fit into the environment they will be used in.

Another reason we may reject the use of checklists is poor construction, including the form, formatting, and content. In Gawande's (2010) Checklist Manifesto, he relates his interview with Daniel Boorman from the Boeing Company in Seattle Washington, a veteran pilot with 20 years of experience developing checklists and flight deck controls. Boorman describes a high-performing checklist as easy to use, as short as possible, precise and efficient, and above all practical, including only the most critical points. Boorman further details that the wording should be simple and exact, use both upper and lower case for ease of reading (preferably a sans serif font), and the list itself should fit on one page and be free of clutter and unnecessary colors. He is also adamant that "a checklist must be tested in the real world" and cautioned that regardless of the effort applied to the design, "first drafts will always fall apart" and must be modified and tested until they work consistently. Acknowledging the necessity of refining and revising checklists is an important principle. Checklists need to evolve and should be dynamic and iterative to respond to changing needs. Sequencing, or the order in which items appear on the checklist, is another important format feature that will greatly facilitate efficiency; if poorly ordered, the checklist will become frustrating and time-consuming. The order of items needs to consider the flow on effect, and the best results will come through collaboration of the entire team providing input, edits, and suggestions for improvement.

In summary, checklists "are not comprehensive how-to guides…they are quick and simple tools aimed to buttress the skills of expert professionals" (Gawande, 2010).

The Sample Checklists

Below is a series of checklists in development at the University of Tasmania. These were first inspired by a checklist in use at New Zealand's National Institute of Water and Atmospheric Research and further informed by a wide range of checklists used around the world by various scientific, technical, commercial, and governmental organizations. They are intended as a first draft with the expectation that they will need to be discussed, clarified, tested, and adjusted multiple times.

Checklist 1 On-Site Risk Assessment (Figure 2)
This checklist includes five topics or areas for assessment and is intended as a team participation activity using the Do-Confirm mode.

Environmental/Worksite Factors
These are the environmental factors present on the site that may impact our safety as divers, or dictate modification of the dive plan, equipment, techniques, personnel, or other risk management controls. Highly experienced field teams often assess these factors intuitively and subconsciously; however, calling them out to the team in a deliberate participatory manner may achieve several benefits. First, it can provide an opportunity to shift the team from automatic, subconscious thinking to a conscious cognitive function, which may improve situational awareness. Secondly, it reaps the benefits of having more than one view of the environment, and the ability of various team members to contribute their experience and knowledge to the environmental assessment. Moreover, it can be used as a development opportunity for newer or less experienced team members.

Emergency Response Capability
The six items in this list may be impacted by the realities of the site and conditions and should be discussed as a team so everyone is clear on any modifications to procedures that may be dictated by location, isolation, or remoteness of the site, including the need to adjust the existing evacuation plan or methods of communication. This section includes prompts to assure that oxygen and first aid equipment has been checked.

Diver and Team Related Factors
The first two items in this section relate to the sufficiency of the team (size, training, and experience) based on what are now known to be the site conditions. The next four items are questions for each diver, and in some jurisdictions are legal requirements. The last two questions are meant to prompt the team to consider how the previous assessments may impact physical demands for the dive operation.

Task Related Factors
The five items in this list should serve as a quick assessment or reminder to the team of any needed modifications based on the results of the above checklist items.

Dive profile modifications
The three items in this list are quick reminders for the team relating to their decompression profile.

ON-SITE RISK ASSESSMENT CHECKLIST University of Tasmania Scientific Diving
Environmental/Worksite Factors
Wind (strength/direction)
Current/Tide (strength/direction)
Sea State
Predicted Weather Changes
Contaminated Water/Biological Hazards
Water Temperature (& thermal protection divers)
Atmospheric Temperature (& thermal protection crew)
Underwater Visibility (& bottom composition)
Maximum Depth of Worksite
Dangerous Marine Animals
Vessel Movement (live-boating or anchorage)
Watercraft Traffic in Area
Emergency Response Capability
Location/Isolation/Remoteness
Evacuation Plan changes/contingencies (incl bushfire)
Communications - types/contingencies
Marine Radio/Satellite Phone/Mobile Coverage
Medical O2 Supply Sufficient & Operation Checked
First Aid Kit Present & Checked
Diver & Team Related Factors
Sufficient Trained Personnel (size/experience of team)
Diver Experience
Diver Fitness/Wellness Pre-Dive
Fatigue, Sleep Deprivation, Distraction
Diver Dehydration
Drugs/alcohol Use
Expected Level of Exercise/Exertion During Dive
Expected Level of Exercise/Exertion Pre & Post-Dive
Task Related Factors
Lifeline Entanglement
Entrapment/Entanglement/Overhead/Confined Space
Animal Handling Methods/Modifications
Equipment Handling Methods/Modifications
Entry/Exit Methods/Modifications
Dive Profile - Modifications
Repetitive Diving
Multi-Day Diving
Planned Travel to Altitude Post-Dive

Figure 2. The On-site Risk Assessment Checklist is designed as a team participation activity.

Checklist 2 Pre-Dive Briefing (Figure 3)
This checklist begins with three prompts, including whether all crew are present, all divers are fit and well, and whether roles have been assigned. The remainder of the checklist is divided into seven areas and is intended as a team participation using the Do-Confirm mode.

Dive Site
Prompts are provided to discuss the dive site, including depth, features, site specific hazards, local regulations, etc.

Dive-Operation Specific Items
These are the mission-critical items such as maximum depth, time, profile, safety stop, buddy procedures, minimum gas limits, and diver-specific tasks/expectations.

Communications/Signals
This includes four items the team needs to agree upon related to how they will communicate during the dive.

Dive termination procedures
These are five points of discussion and decisions for the team that relate to terminating or aborting a dive and any procedures the team may have for that. Frequently we have heard from divers that it is psychologically easier to terminate/abort a dive when they have been reminded during the briefing that they have not only the right but the responsibility to stop a dive for any reason.

Diver emergency procedures
This includes three high-priority prompts that are intended to create a link to known and practiced procedures. This is some of the 'stupid stuff' that is often missed on dive briefings because there is an assumption that everyone knows how to handle these. Discussing them as a team can reinforce not only the diver's responsibilities, but the responsibilities of the rest of the team as well.

Surface Attendant/Standby Duties
These three prompts are intended to elicit brief discussion regarding how any topside (e.g., shore/vessel) crew will track the divers, identify problems, conduct rescue, and evacuate injured team members.

Questions
This one-word prompt is a reminder that all team members have a voice and to encourage active participation.

PRE-DIVE BRIEFING CHECKLIST **University of Tasmania** **Scientific Diving**
All Crew Present
Divers Fit and Well (alcohol, decongestants, hydrated)
Roles Assigned (divers/attendant/standby)
Dive Site
Orientation: Depth/Topography/Features
On-site Risk Assessment Complete?
Reminders on Site Specific Hazards
Local Regulations/Restrictions
Dive-Ops Specifics
Task/Procedures for each Phase of Dive Op
Briefing each Diver- specific tasks
Equipment to Be Used
Max Depths and Times (Profile)
Direction & Course of Travel U/W
Confirm Turnaround Time/SPG
Safety Stop
Minimum SPG to Leave Bottom/Begin Ascent
Buddy System procedures
Entry/Exit Procedures
Communications/Signals
Diver to Diver
Diver to Surface
Surface to Diver
Diver Recall Signals
Dive Termination Procedures
Minimum Gas Requirements
Time/Profile/Scrubbed Duration
Fatigue, Cold, Distraction, Any Reason
Oxygen Toxicity Limits
Surface Initiated (weather, vessel, etc)
Diver Emergency Procedures
Low Gas/Out of Gas/Gas Problems
Buddy Separation
Missing Diver
Surface Attendant/Standby Duties
Tracking Divers/Recognise Problems
Rescue procedures
Evacuation Procedures
Questions?

Figure 3. Pre-Dive Briefing Checklist

Checklist 3 Deploy Diver Checks (Figure 4)
This checklist includes six sections, pre-dive preparation, sampling/science equipment, life-support dress-in, accessory dress-in, diver deployment, and post-dive. If this checklist is used in a Do-Confirm mode, where many of the items may have already been completed by the diver, it should take less than three minutes. NIWA and several other organizations report using the Read-Do mode for this checklist for better accuracy. Note that due to cognitive biases, it is worth checking these use a pointing and calling process as described previously. The Read-Do mode is also very appropriate for training purposes. When using CCR units, the checklist will need to be modified to take into account gases, setpoints, and scrubber durations.

Checklist 4 Post-Dive Briefing (Figure 5)
This checklist has been populated entirely from The DEBRIEF Model provided by Gareth Lock (The Human Diver Limited) and is reprinted with permission (Lock 2019). A greater level of detail can be found in the Teamwork chapter of Under Pressure (Lock 2019). The DEBRIEF model is intended to be used as part of a systematic approach to teamwork and embraces the concept of improving performance by creating psychological safety, learning from our own, and the team's areas for improvement, as well as acknowledging and then reinforcing what is already working well. Finally, the DEBRIEF structure highlights that unless something is changed, adapted or modified for future operations, the lessons are only identified and not necessarily learned.

Summary

A quality checklist can enhance not only the safety, but the overall performance of the teams using them. They can be a useful tool to improve decision-making, simplify and verify tasks, and manage complexity. They can help us capture the "stupid stuff" leaving room for the professional to use their skills and expertise to best effect. Checklists require a collaborative effort with the users to assure they are well designed, fit for purpose, and foster effective communication between team members. The manner of how checklists are introduced and implemented is a key element of success, including an understanding that they should be dynamic and revised regularly. This paper presented a series of sample checklists for scientific diving and invites the community to review them, revise them, test them, and share their experiences and comments with the authors for further development.

DEPLOY DIVER CHECKLIST University of Tasmania Scientific Diving Checklist
Pre-Dive Prep
SPG at Zero Before Turning on Gas Supply
Gas (type/volume) Adequate & Recorded
Gas Analysed & Recorded MOD checked (EAN)
Dive Computer Function/Battery check
Gas Mix Entered into Computer
Compare Planned Profile to Computer Status
Communication Equipment Pre-Check
Dive Flag Up
Sampling Equipment (Project Specific)
Prepped/Functional/Good Condition
Life Support Dress In
Back Gas Valves OPEN
Hoses Good Condition/Secure/ Routed Correctly
Breathing Check both Regulators
Mouthpieces Secure/Intact both Regs
SPG Clipped Off/Pressures Recorded
BCD Check incl Inflation & Connections
BCD Dump & OPV Function
Cylinder secure to BCD
Sling Gas Px Check/Hose Charged/Valve On-Off
Weight Adequate/Secure/Releases Checked
Drysuit Zippered/Seals checked/Inflation/Deflation/Connections
Accessory Dress In
Dive Compass & Computer On diver
Cutting Devices Secure/Accessible both Hands
Hood & Gloves
Mask and Snorkel
SMB & Wet Notes
Comms check (if using)
Standby Diver Ready? (incl. checklist to here)
Diver Deployment
Enter by Safest Means
Signal to Surface all OK
Post- Dive
All Divers Well & Accounted For
RECORD Depth, Bottom Time, Gas Pressures/sign log forms
Any Gear Issues - Tagout Defective Equipment
Report Any Incidents, Near Miss, Hazards
Note Planned vs Actual Exercise/Exertion
Notify Divers of Profile Status/Restrictions (Altitude/Heavy Work)

Figure 4. The deploy diver checklist codifies a great deal of technical knowledge into brief prompts.

POST-DIVE DEBRIEFING CHECKLIST University of Tasmania Scientific Diving
Define
Aims/Goals/Objectives of the dive and did we achieve them?
Time/Scope of the debrief to manage expectations of time.
Example
Set example as leader. Talk about a mistake you made
Set the scene that it is ok to talk about errors/learn from failures
Basics
Basics & admin of the dive
(entry time, logistics and the plan)
Was plan achievable,
did it need to be changed before/during dive?
What could be improved about pre-dive aspects?
Focus on non-operational aspects of dive.
Review Execution
Chronologically step through the execution against
the plan, highlighting key points.
Focus on key highlights so that learning is managed.
Level of detail may vary from top level to real detail.
What happened & why rather than future learning points
Internal
One thing I did well. Why?
One thing I need to improve. How will I do that?
Each team member answers in turn, starting with leader
External
One thing we as a team did well. Why?
One thing we need to improve. How will we do that?
Focus is on team aspects of the dive.
Be specific, no generalities
Describe what worked and why.
Follow-up/File Report
Reinforce what needs to be done following debrief
Includes file incident or learning report
Examples: modification of equipment,
revision to planning assumption,
post report where others can learn of event. Share the Learning!
Source of Content: The DEBRIEF model © The Human Diver 2019 Re-printed with permission

Figure 5. The DEBRIEF model is part of Gareth Lock's Non-Technical Skills/Human Factors program.

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