

SPUMS ANNUAL SCIENTIFIC MEETING 1996

“TECHNICAL” DIVING AND DIVER PERFORMANCE: A PERSONAL PERSPECTIVE

Michael Davis

Key Words

Mixed gas, nitrogen narcosis, performance, rebreathing.

Introduction

Whatever the nature of the diving activity being undertaken, whether it is a sport scuba shore dive in perfect, balmy tropical, conditions or a saturation diving operation, like recovering the gold from HMS Edinburgh above the Arctic Circle, in its planning the same broad principles always apply (Table 1). As an example of the increasing complexity that a particular task underwater may require I shall use as an historical example my own introduction to “technical diving” over 30 years ago as an undergraduate student in a university British Sub-Aqua Club (BS-AC) branch in England.¹ I hope that describing this project will, in the process, identify many of the important challenges to be met in the transition from open circuit scuba-air to mixed gas semi-closed rebreather diving, thus providing a reference point during the conference. At the same time I wish to make a few comments about the efficiency of divers underwater, again largely using historical data from diving experiments in the 1960s and 1970s in which I or close colleagues took part.

Dive planning

It is a truism that the most important component of dive planning is to define the **Purpose(s)** of the dive(s) (Table 1). If the complexity or risks of a particular dive are greater then, on a risk/benefit basis, the justification for doing it must be stronger. Therefore, clear goals should be set and these determine the choice of diving techniques to be used, selecting and training of a diving team and so on.

The purpose of Nic Flemming’s project was to study the physical structure of sand ribbons in the English Channel several miles offshore at a depth of 40-60 m. We initially attempted this in 1964 on scuba-air, but the working conditions underwater so reduced the intellectual ability of the divers that several experiments had to be abandoned. Such an outcome was probably predictable, but at least led to a careful review of how the scientific goals might better be achieved.

The decision was made to move to oxygen-helium (heliox) mixtures. This had the secondary effect of

TABLE 1

DIVE PLANNING

PURPOSE

Defining the purpose of the diving determines:

Techniques

Scuba / SDBA / Rebreathers / Bell / Saturation

Personnel:

Personalities / Experience / Expertise / Motivation / Team Size

Equipment and Gas Mixes

Purchasing / Preparation / Maintenance

Training

Equipment / Diving techniques and procedures

Planning

Dive program(procedures / decompression) / Support infrastructure / Emergencies

Execution

Diving / Weather / The Unexpected

Outcome

Was the original purpose achieved?
What were the health and financial costs?

broadening the scope of the planned diving and the initial phase, run in the Mediterranean, constituted the first ever open-water studies on diver performance comparing air and heliox.

TECHNIQUES, EQUIPMENT AND GAS MIXTURES

The upshot of this was the assembly, by the Admiralty Experimental Diving Unit (AEDU), of a semi-closed rebreather of sufficient capacity for 75/25 helium-oxygen diving to 70 m. This was made by attaching two 50 cu ft. SABA (Swimmer’s air breathing apparatus) cylinders for the heliox mix through a second fixed flow rate reducer (set at 32 l/min) to a CDBA (Clearance diver’s breathing apparatus) counterlung with a separate oxygen supply. It was not until several years later that those of us taking part fully appreciated just how much of a prototype this set was and that we were, in fact, trialling the Royal Navy’s first ever such equipment for them!

PERSONNEL AND TRAINING

Selecting the size and make up of the dive team largely came down to those undergraduate club members with enough time and money to take part in the winter training and five weeks of diving during the summer vacation. Of the eight-man team only two had more than

two years' diving experience and two divers had never dived deeper than 30 m before.

Theory training was based on the RN and USN Diving Manuals, group discussions and the exciting intellectual stimulus of talking with such people as Drs Hempleman, Barnard and Elliott at the Royal Naval Physiological Laboratory (RNPL) in Alverstoke. Initial practical training on the operation and maintenance of the set was conducted at AEDU though, in retrospect, this was very limited, with each diver doing only one to four hours on the set before commencing deep open water dives!

The proposed decompression procedures for a bottom time of 15 minutes at depths of 30, 45 and 60 m were tested at RNPL. The empirical nature of developing tables was brought home strongly to us by the way in which our planned stops were changed firstly following two bends during the chamber dives at RNPL and then later after the Navy's first unsatisfactory open water experiences with their heliox tables deeper than 60 m shortly before our summer season of diving (Table 2).

In practice then, team selection was based largely on happenstance and enthusiasm, training was minimal by modern standards and the decompression tables were essentially untested!

PLANNING AND EXECUTION

The conduct of the diving program was described in detail by Flemming.¹ As this publication is difficult to obtain I am willing to supply copies on request. In summary, despite our limited training, no operational problems arose with the heliox set either during the performance studies conducted in Malta, nor during the geological diving off Plymouth. The amount of

preparatory work for each dive was considerable and seven men were actively engaged in its conduct each time. The only problem we encountered was that the capacity of the twin 65 cu ft open circuit air set was sometimes insufficient for the 60 m dives, requiring staging of extra cylinders for decompression. The decompressions for the air and heliox dives to the same depth and time were very different (Table 2).

That one cannot plan for every eventuality was exemplified by three totally unexpected problems. Several of the heliox storage cylinders were delivered with slow leaks, seriously reducing the amount of mix available in Malta. Then the project leader's wife, who was with us, required major emergency surgery in the middle of the Malta dive program. Finally, a road accident in Italy on the way back for the English Channel diving leg, destroyed one of the semi-closed sets though, fortuitously, not the car occupants.

OUTCOME

Using heliox in the English Channel resulted in our achieving as much in one week's diving as we had in a month on air. Interestingly, the geomorphology project was, in fact, finally completed a few years later using a submersible! The diver performance studies provided valuable data² and raised issues regarding the relationship between narcosis and performance for much further research.³

Diver performance

The disparate techniques embodied in the nebulous term "Tek Diving" take us into a different range of risk-benefit and cost-benefit decision making than that for open-

TABLE 2

The decompression schedules for air and 75/25 heliox for a 15 min bottom time at 60 metres. The first heliox column is the planned profile, and the second the actual profile used for the dives. Gas mix for each stop is shown.

Depth m	Air dive stops		Heliox (planned) stops		Heliox (actual) stops	
	Minutes	Breathing gas	Minutes	Breathing gas	Minutes	Breathing gas
18	-		3	HeO ₂	5	HeO ₂
15			3	HeO ₂	5	HeO ₂
12			3	HeO ₂	5	HeO ₂
9	5	Air	3	O ₂	10	O ₂
6	5	Air	6	O ₂	10	O ₂
3	20	Air	15	O ₂	20	O ₂
Total decompression time	30		33		55	

circuit scuba-air diving to 40 m. The increasing demand for these techniques is because, in the simplest terms, tekkies want to dive longer, deeper, more safely and more easily.

The last, more easily, is summed up by Flemming's comment on heliox use in the English Channel.¹ "The impression of clarity of vision and thought was so startling that it was almost like seeing the sea floor for the first time." I wish to focus on one aspect of making it easier by briefly discussing nitrogen narcosis and its relationship to the wider concept of diver performance.

When people are required to work under conditions which deviate from the biological norm, such as underwater, they may be said to be operating under stress.³ Whether these stresses improve or impair performance will depend on the type and degree of the stress(es) and the nature of the task(s). In diving the interactions are obviously complex and difficult to control, making the outcome unpredictable.

Experiments over the past 40 years have attempted to study the independent impact of such factors as nitrogen narcosis,^{3,4} cold,⁵ spatial perception,⁶ drug interactions,⁷ gas mixes⁸ etc., and then to consider the results observed, whether derived from simulated dives in a chamber or underwater experiments, in relation to open-sea conditions where the whole gamut of factors operate simultaneously. Conversely, many different tasks have been tested, from simple isolated manual or intellectual tasks, often employed in batteries of tests^{8,9} to complex sub-sea structure assembly employing the interaction of several divers,¹⁰ in order to understand better how divers function underwater.

What has emerged is a realisation that there are wide differences in the susceptibility of different tasks to the effects of various stresses, and that the final interaction of diver, environment and task varies considerably. What does that all mean? Simply, that what you achieve on a given dive might be as much in the lap of the gods as anything

else! The concept of diver performance, then, is a complex entity influenced by many factors (Table 3).¹¹

I will use nitrogen narcosis as an example of how this picture has been built up from various experiments, mainly those conducted or supervised in the 1960s and 70s by Professor Alan Baddeley, who has been one of the pioneers of field work on diver performance. For an extensive review of nitrogen narcosis the reader is referred to Fowler et al.¹²

Every novice diver knows about nitrogen narcosis, Jacques Cousteau's "raptures of the deep", and how the brain is progressively impaired by increasing partial pressures of nitrogen with depth, the so-called Martini's Law! Nitrogen narcosis is written about in diving texts and taught to sports, commercial and military divers as the overriding factor far outweighing everything else in its effects on diving safety and efficiency for any diving beyond about 25 m. Therefore, avoidance of narcosis is listed amongst the main rationalisations behind the development of sport diving techniques other than scuba-air.

Yet how accurate is this picture? Take for instance the results for one simple manual dexterity task, transferring nuts and bolts from one set of holes in a metal plate to another set, which has been used widely in diving studies. Figure 1 summarises the data from six experiments. Graphs A and B show the change in performance in a dry recompression chamber for 75/25 heliox and air respectively. Essentially there is almost no deterioration to 60 m with heliox, but a significant, though small, fall with air at 30 m, demonstrating the narcotic potential of nitrogen.^{12,13}

Now examine graphs E, F, G and H, taken from open water air diving studies in varying conditions. The two most striking features here are, firstly, the marked fall in performance simply with immersion in shallow warm water and, secondly, the variation in further performance decrement at 30 m depth.

TABLE 3

THE MAJOR FACTORS INFLUENCING THE PERFORMANCE OF DIVERS IN OPEN WATER CONDITIONS.

Physiological	Behavioural	Environmental
Inert gas narcosis	Training	"Immersion effect"
CO ₂ retention	Experience	Reduced light
Hypothermia	Motivation (arousal)	Reduced visibility
Hypoxia	Anxiety	Weightlessness
Gas impurities	Reduced sensory input	Mechanical restriction
Drug interactions	(all modalities)	Water movement

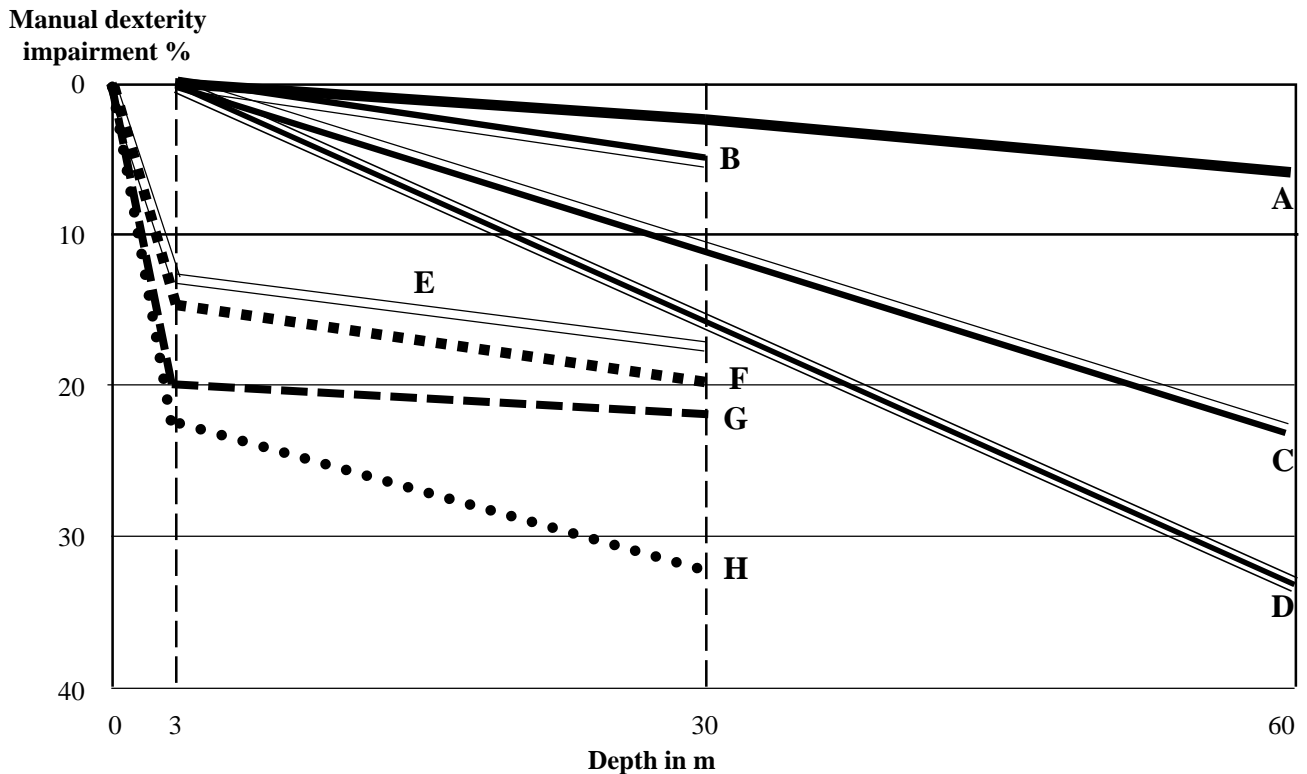


Figure 1. Change in performance of a manual dexterity test during simulated dives in a chamber (curves A and B) or in open water (all other curves) from six published studies.¹¹⁻¹⁴ See text for details. All data normalised and expressed as percentage change from the control condition (either dry land, curves E, F, G and H, or 3 m depth, curves A, B, C and D).

The “immersion effect” on performance has occurred in all published studies of manual performance where it has been looked for and is also present for some measures of intellectual performance such as aspects of memory. The implication of this for diving is that learned skills are often best performed in the conditions under which they were learnt. To turn that on its head and apply it to technical diving, tasks learnt in a swimming pool will not necessarily be properly recalled or performed under operational conditions. One must train divers in the skills they need **in the environment they will be exposed to**. In practice, of course, this is not always possible.

Why do the slopes of E, F, G and H in the water differ? Experiment H was performed at sea from a dive vessel in moderate diving conditions using, as subjects, relatively inexperienced divers, few of whom had dived to 30m before.¹³ Experiment G was performed from a stone jetty in idyllic, calm, clear warm waters using divers used to much harsher conditions,¹⁴ while Experiments E and F fell somewhere in the middle.¹¹

Thus the performance decrement with depth reflects not only the effects of nitrogen narcosis itself but also an interaction of other factors believed to result in heightened anxiety in the diver.^{3,11} Some of these factors are summarised in Table 3. Open water studies to test this

hypothesis, looking at physiological variables and psychometric evaluation at the same time, have been inconclusive,¹⁵ and this remains an area still requiring good research.

What then of the performance advantages under operational conditions of moving to a non-narcotic gas mixture such as 75/25 heliox at 60 m using semi-closed rebreathers? It can be clearly seen from graphs A, C and D that there is a significant deterioration in performance in open-sea conditions compared to a chamber environment *irrespective of the gas mixture used*.² In addition, divers generally performed worse at this depth on air than they did on heliox. However, this was *not* universally the case. Similar results were obtained during the US Navy Sea Lab II project, where performance at depth in the habitat was unimpaired while performance outside in the sea showed a marked deterioration.¹⁶

Conclusion

In this presentation I have briefly described my personal experiences on a diving project in the mid 1960s run by a group of postgraduate and undergraduate student members of a BS-AC branch using semi-closed rebreathers and heliox gas mixtures to depths of 60 m. This illustrated

many of the general principles of dive planning and the specific challenges of so-called technical diving.

From this work an understanding evolved that impaired diver performance is not synonymous with nitrogen narcosis and that the latter is only one of many factors that come to play a part in determining the effectiveness of working divers, be they hunter, photographer, scientist or commercial diver.

References

- 1 Flemming NC. Operational diving with oxy-helium self-contained diving apparatus. *Symposium of the Underwater Association for Malta* 1965, 3-12
- 2 Baddeley AD and Flemming NC. The efficiency of divers breathing oxy-helium. *Ergonomics* 1967; 10: 311-319
- 3 Baddeley AD. Diver performance and the interaction of stresses. In *Underwater Association Report 1966-67*. Lythgoe JN and Woods JD. Eds. Underwater Association of Malta 1966 Ltd, 1966; 2: 35-38
- 4 Bennett PB. *The Aetiology of Compressed Air Intoxication and Inert Gas Narcosis*. London: Pergamon Press, 1966
- 5 Davis FM, Baddeley AD and Hancock TR. Diver performance: the effect of cold. *Undersea Biomed Res* 1975;2:195-213
- 6 Ross HE. Spatial perception underwater. In *Underwater Science*. Woods JD and Lythgoe JN. Eds. London: Oxford University Press, 1971; 69-101
- 7 Williams TH, Wilkinson AR, Davis FM and Frampton CMA (1988). Effects of transcutaneous scopolamine and depth on diver performance. *Undersea Biomed Res* 1988;15: 89-98
- 8 Logie RH and Baddeley AD. Cognitive performance during simulated deep-sea diving. *Ergonomics* 1985; 28: 731-746
- 9 Bittner AC, Carter RC, Kennedy RS, Harbeson MM and Krause M. Performance evaluation of tests for environmental research (PETER): evaluation of 114 measures. *Percept Mot Skills* 1986; 63: 683-708
- 10 Weltman G, Smith JE and Egstrom GH. Perceptual narrowing during simulated pressure chamber exposure. *Human Factors* 1971; 13: 99-107
- 11 Davis FM, Osborne JP, Baddeley AD and Graham IMF. Diver performance: nitrogen narcosis and anxiety. *Aerospace Med* 1972; 43: 1079-1082
- 12 Fowler B, Ackles KN, and Porlier G. Effects of inert gas narcosis on behaviour: a critical review. *Undersea Biomed Res* 1985; 12: 369-402
- 13 Baddeley AD. Influence of depth on the manual dexterity of free divers: a comparison between open sea and pressure chamber testing. *J Appl Psychol* 1966; 50: 81-85
- 14 Baddeley AD, de Figueredo JW, Hawkswell-Curtis JW

and Williams AN (1968). Nitrogen narcosis and performance under water. *Ergonomics* 1968; 11: 157-164

- 15 Davis FM, Charlier R, Saumarez R and Muller V. Some physiological responses to the stress of aqualung diving. *Aerospace Medicine* 1972; 43: 1083-1088
- 16 Bowan HM, Anderson B and Promisel D (1966). Studies of divers' performance during the Sea Lab II project. *Human Factors* 1966; 8:1 83-199

Dr F Michael Davis, MD, FANZCA, DipDHM, is Medical Director, Hyperbaric Medicine Unit, Christchurch Hospital, Christchurch, New Zealand. Fax + 64-3-364 0187.

MENTAL FITNESS IN TECHNICAL DIVING FOR SPORT SCUBA DIVERS

Sonnhild Schiöberg-Schiegnitz

Summary

Technical diving requires not only elaborate technical equipment but the appropriate readiness to come to terms with the necessary technical basic knowledge. Technical diving requires a particularly high level of self-control mechanisms. An essential part of the examination for diving is assessment of emotional stability, reliability, capacity for self-control, intelligence and social behaviour. These are fundamental for safe diving. Mental training is one component of training designed to pre-program the brain's solution-paths and behaviour sequences by thinking them through repeatedly and practising repeatedly until they run reflexly in critical situations.

Keywords

Fitness to dive, mixed gases, performance, recreational, training.

Introduction

The main cause of diving accidents is human failure. Decompression sickness is a bodily organic illness but, in most cases, it is wrong human behaviour which is the triggering factor. There have been extensive studies of diving accidents triggered by human factor.

Technical diving poses particular demands on the sportsman's personality. Technical diving is not a spontaneous recreational activity, just for fun, but requires