NAVSEA - Hypercapnea Narcosis: Study Protocol Validation with the MATB-II software

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INTRODUCTION

- US Navy stated the need for an algorithm to compute "equivalent narcotic depth" for various inspired breathing gas partial pressures.

- Known: Elevated PaN_2 causes narcosis at depth

- Known: Elevated $PaCO_2$ can occur in divers[1-4]
  - depth-related hypoventilation from elevated breathing gas density/breathing resistance
  - limitations of CO2 absorbent function

- In the setting of nitrogen narcosis, elevated PaCO2 may further increase narcotic effects → cognitive deficit → mission failure[5-8]

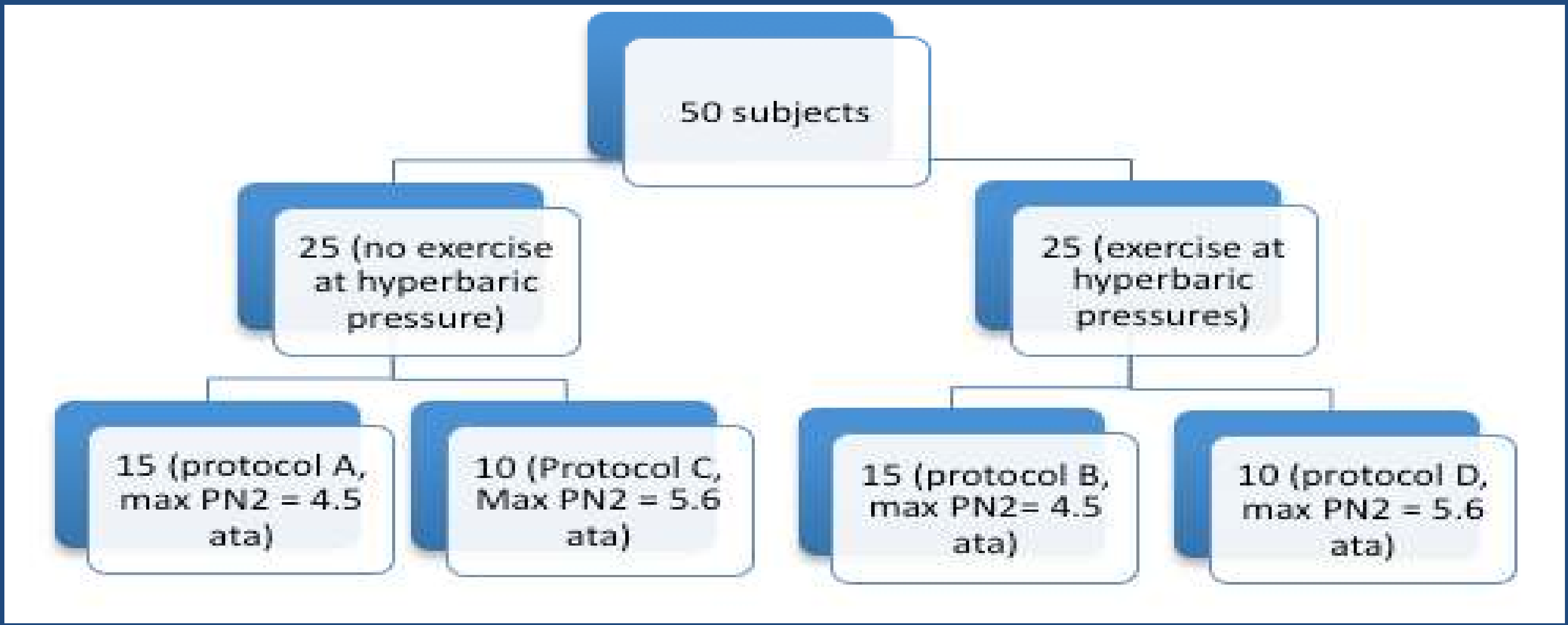
INTRODUCTION

- End tidal carbon dioxide ($P_{ET}CO_2$) is a reasonable surrogate for $PaCO_2$ under resting conditions at the surface and up to moderate elevations (50-55 mmHg) [9-10]
  - Unknown if reliable during exercise, at depth

- Study goals:
  - To better define the human physiology of CO_2 elimination at increased depths and gas densities
  - Qualify the effects of CO_2 on nitrogen narcosis
  - Quantify the interaction between the partial pressures of CO_2, O_2 and N_2 on cognition
  - Construct an algorithm to compute "equivalent narcotic depth" based on inspired partial pressures of these gases.
  - Establish the relationship between $P_{ET}CO_2$ and $PaCO_2$ in the upper range of interest (50-70 mmHg) during immersed rest and hyperbaric exercise
  - Construct an algorithm to predict $PaCO_2$ from $P_{ET}CO_2$ in immersed exercising divers.

METHODS

50 subjects randomized into one of four protocols designed to simulate a working diver under various conditions.



Surface Phase

Surface Phase Protocol is identical across all four protocols

Experimental Condition	Est time min	Expt stage	Depth (fsw)	P(ATA)	Gas Density at 37°C (g/L)	Work Rate (W)	Inspired PCO2 (mmHg)	PO2 (ATA)	PN2 (ATA)	EAD (fsw)
	60	Subject preparation / Equipment calibration / Gas confirmation								
1	5	1.1	0	1	1.13	-	0	0.2	0.8	0
2	5	1.2	0	1	1.13	-	+	0.2	0.8	0
3	5	1.4	0	1	1.26	-	0	1.0	0	-
4	5	1.3	0	1	1.26	-	+	1.0	0	-
		Begin surface exercise								
5	5	1.5	0	1	1.13	+	0	0.2	0.8	0
6	5	1.6	0	1	1.13	+	+	0.2	0.8	0
7	5	1.8	0	1	1.26	+	0	1.0	0	-
8	5	1.7	0	1	1.26	+	+	1.0	0	-
	60	Rest at surface / Equipment calibration / Gas confirmation								
		Begin Dive Protocol								

Constant: Low PN2

Variables: Elevated PCO_2

Elevated PO_2

Exercise

Each segment:

2 minute equilibration

3 minute cognitive test

ABG

ET gas monitoring

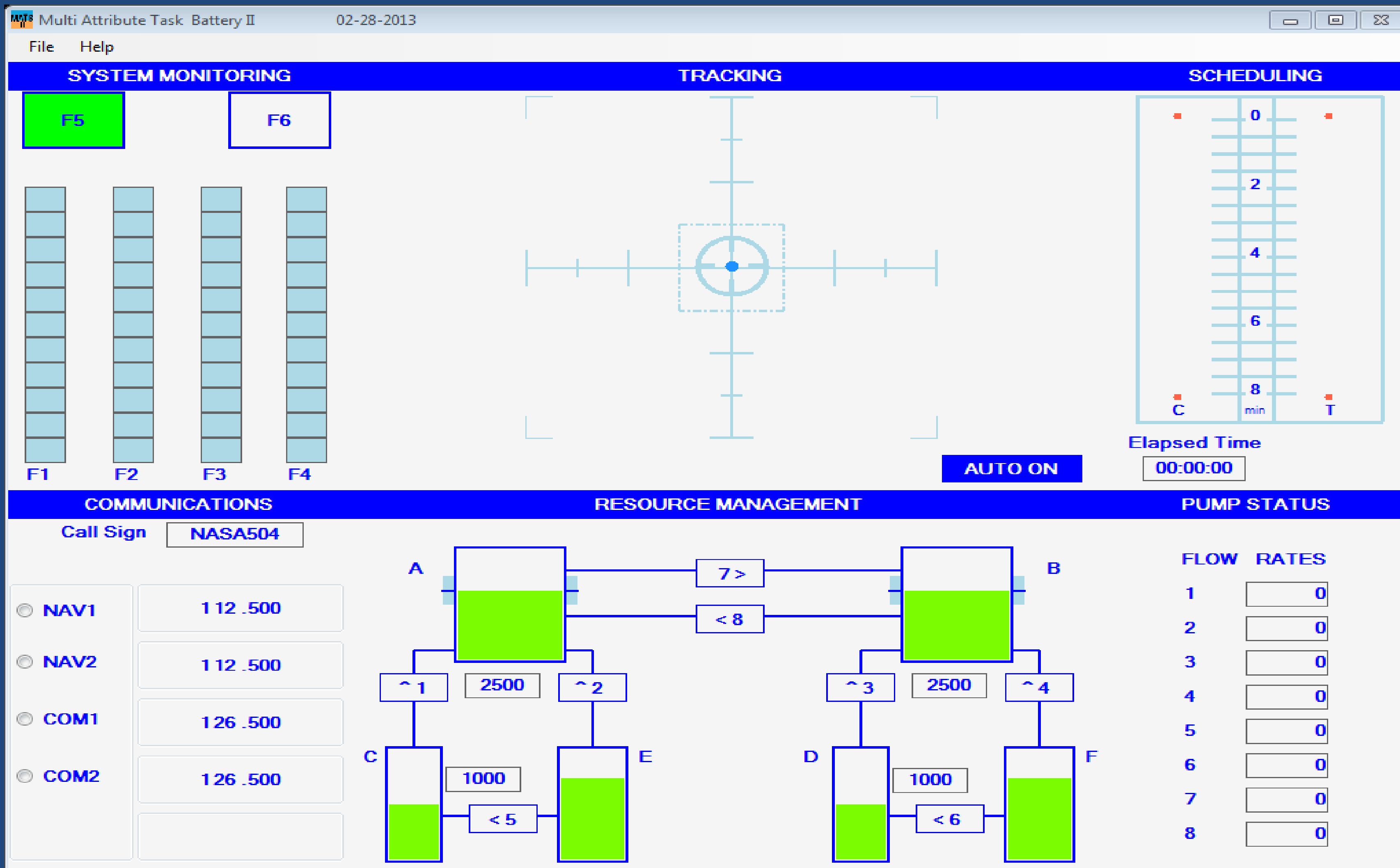
Hyperbaric Phase

Protocol	Subjects	Exercise	Depth (fsw)	Added CO_2	PO_2 (ata)	PN_2 (ata)	EAD (fsw)
A	15	-	122 158	+/-	0.2, 1.3	4.5	158
B	15	+	122 158	+/-	0.2, 1.3	4.5	158
C	10	-	158	+/-	0.2	5.6	200
D	10	+	158	+/-	0.2	5.6	200

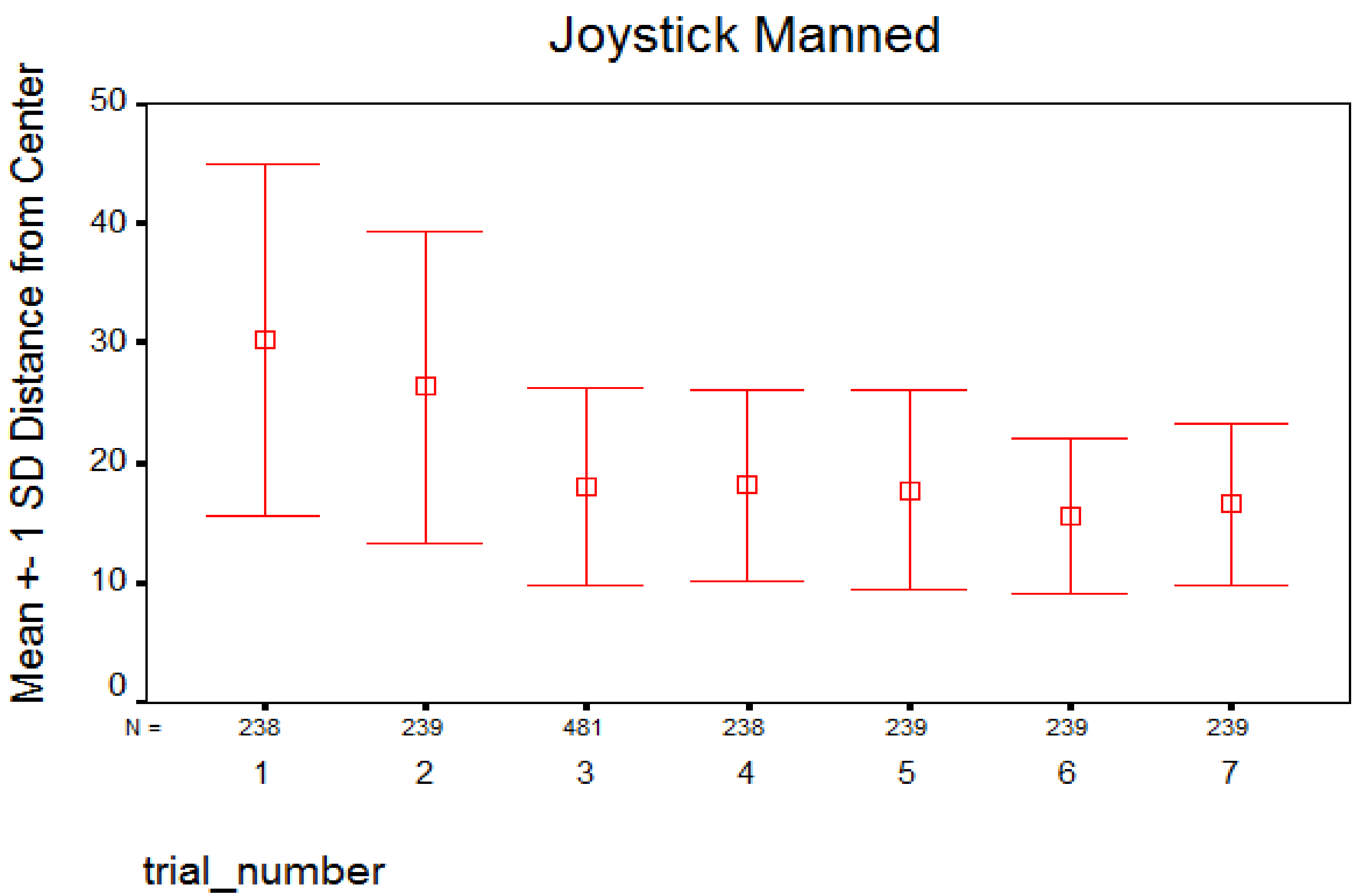
- Deper operational depths than recreational SCUBA
- Same variables, but now elevated PN_2

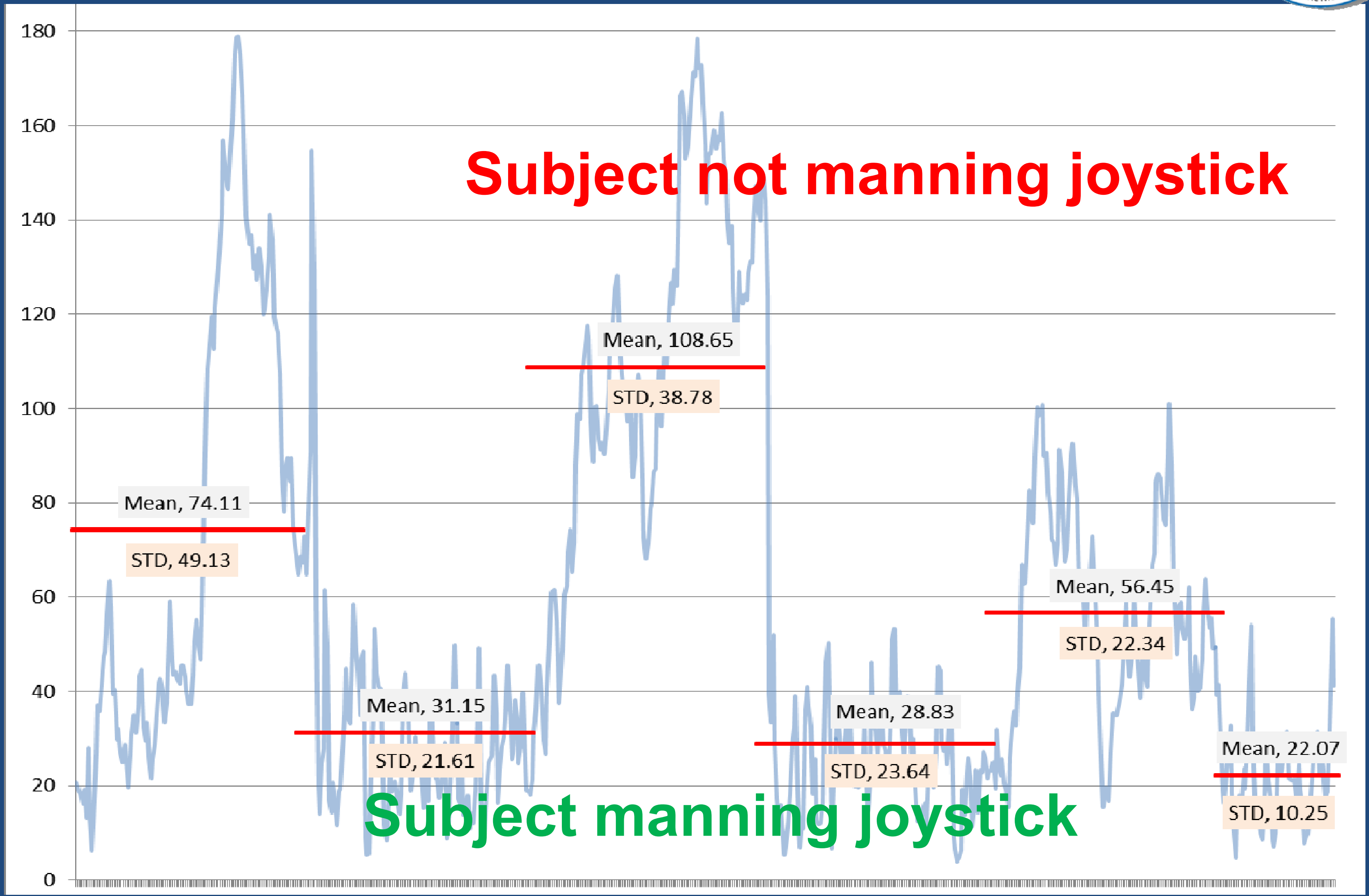

Airgas

Cognitive Testing: Multi-Attribute Task Battery Version 2 (MATB-II) – tracking and monitoring



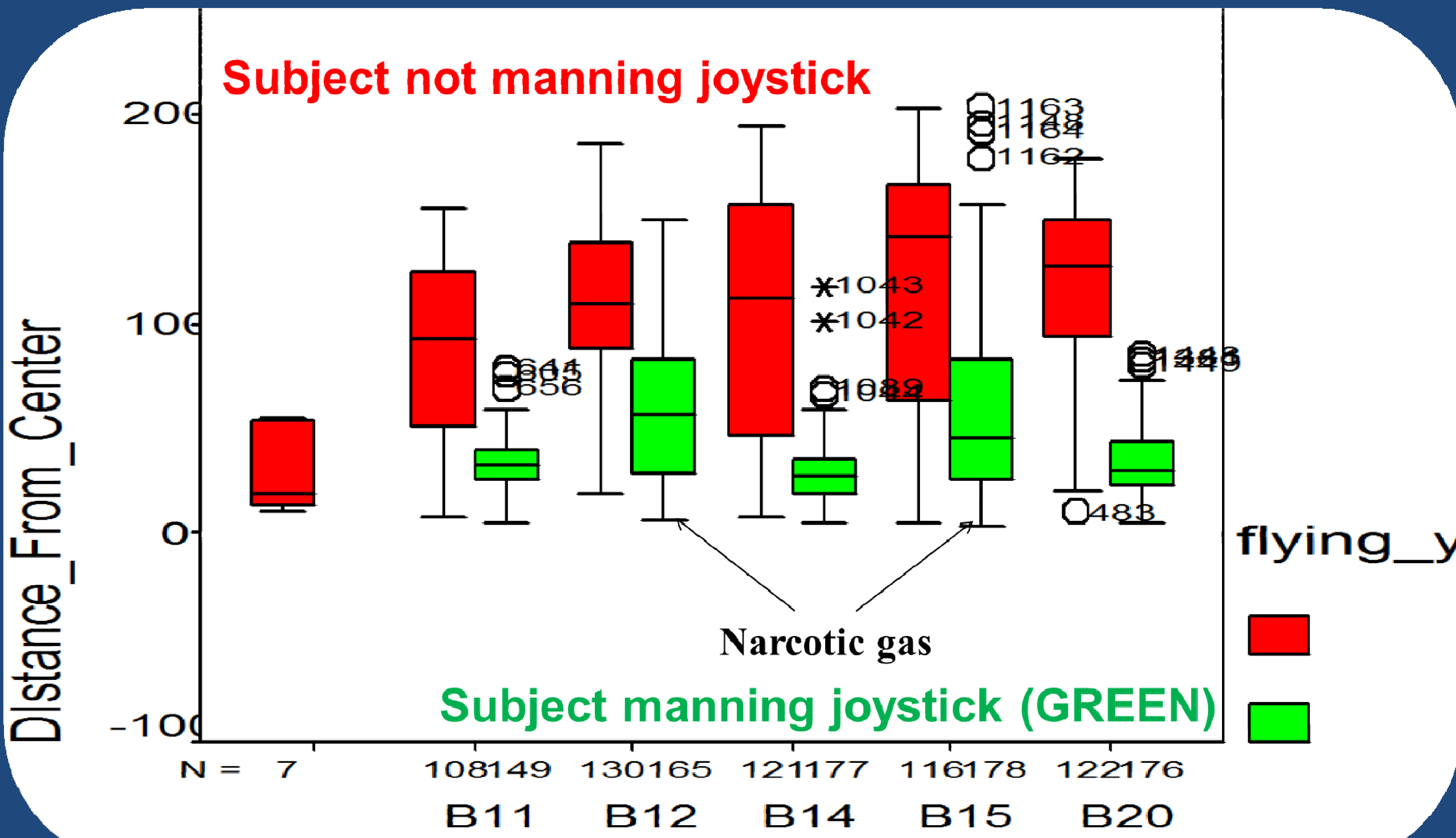
Performance Plateau Testing for Tracking Task



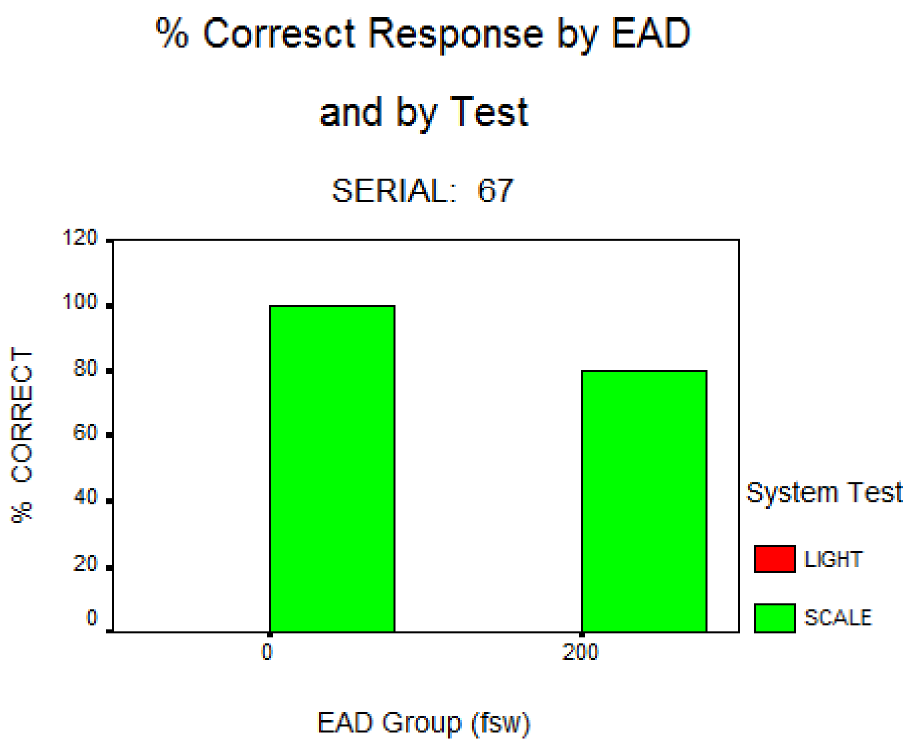

Subject not manning joystick
Subject manning joystick
Mean, 74.11
STD, 49.13
Mean, 31.15
STD, 21.61
Mean, 108.65
STD, 38.78
Mean, 28.83
STD, 23.64
Mean, 56.45
STD, 22.34
Mean, 22.07
STD, 10.25
180
160
140
120
100
80
60
40
20
0

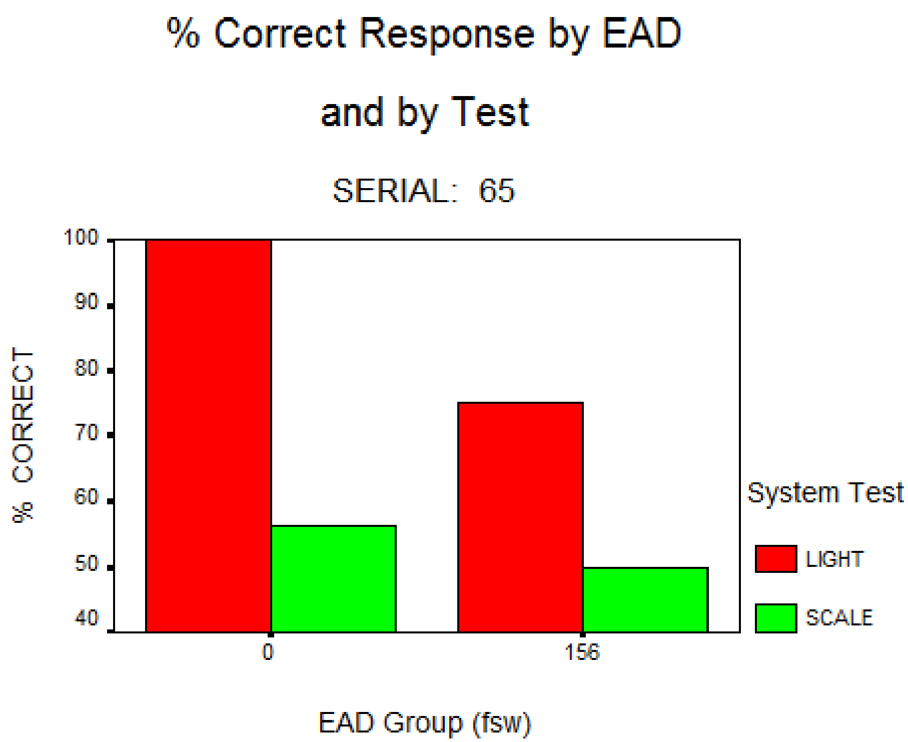
Sample Trial Results

EAD 200’, no exercise, PCO_2 0.075



System Monitoring Performance





CONCLUSIONS

- Performance plateau with the MATB-II with 10-20 minutes of practice
- A subject familiarization day will be added to the protocol
- The MATB-II software will be modified to perform at a consistent level of difficulty without requiring restart in order to minimize task loading on investigators during this complex protocol.
- The MATB-II detects decline in cognitive performance with both tracking and monitoring tasks.
- The study will take 3 years. Software and procedures will be developed and piloted on 10 subjects during year one. During years 2-3, studies will be performed on an additional 40 subjects.
- A final report prepared in year 3 will provide: 1) a prediction equation for $PaCO_2$ as a function of $P_{ET}CO_2$ with values up to 70 mmHg; 2) an algorithm to compute equivalent narcotic depth on the basis of inspired N_2, O_2 and CO_2 partial pressures (and/or end tidal PCO2).

ACKNOWLEDGEMENTS

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