NAVSEA 1 – Measurement of Nitrogen and Hypercapnic Narcosis Using NASA's MATB-II Software

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INTRODUCTION

- Elevated nitrogen partial pressure (PN_2) can decrease cognitive performance by causing narcosis during deep air diving.
- Elevated arterial partial pressures of carbon dioxide ($PaCO_2$) and oxygen (PaO_2) may further increase the overall narcotic effect.
- The US Navy has need to predict the degree of cognitive performance deficit associated with the narcotic gases a working diver may experience at operationally relevant depths.
- Monitoring inspired (P_i) or end-tidal (P_{ET}) CO_2 during a dive is a theoretically practical way for a diver to be warned of impending narcosis.
- $P_{ET}CO_2$ is a reasonable surrogate for $PaCO_2$ under resting conditions at the surface and up to moderate elevations (50-55 mmHg) during exercise at depth. *However,* it is unknown whether $P_{ET}CO_2$ can be relied upon to predict PaCO2 at higher levels.

- **This series of experiments is designed to:**

(1) Quantify the effects of elevated $PaCO_2$ and PaO_2 on nitrogen narcosis.

(2) 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.

(3) Use this information to construct an algorithm which can predict $PaCO_2$ from $P_{ET}CO_2$ and correlate this to an “equivalent narcotic depth” for $PaCO_2$ in the working deep sea diver.

STUDY DESIGN

- The Multi-Attribute Task Battery-II (MATB-II) is a NASA developed, computer based flight simulation software designed to evaluate operator cognitive performance and workload during an operationally realistic scenario. *(See Abstract)*

- 8 Pilot subjects were studied during head-out immersion at rest and at 50 watts of output on an exercise cycle ergometer.

- $PaCO_2$ and $P_{ET}CO_2$ were measured by arterial blood gas and mass-spectrometry respectively at sea-level and hyperbaric conditions, with and without exercise.

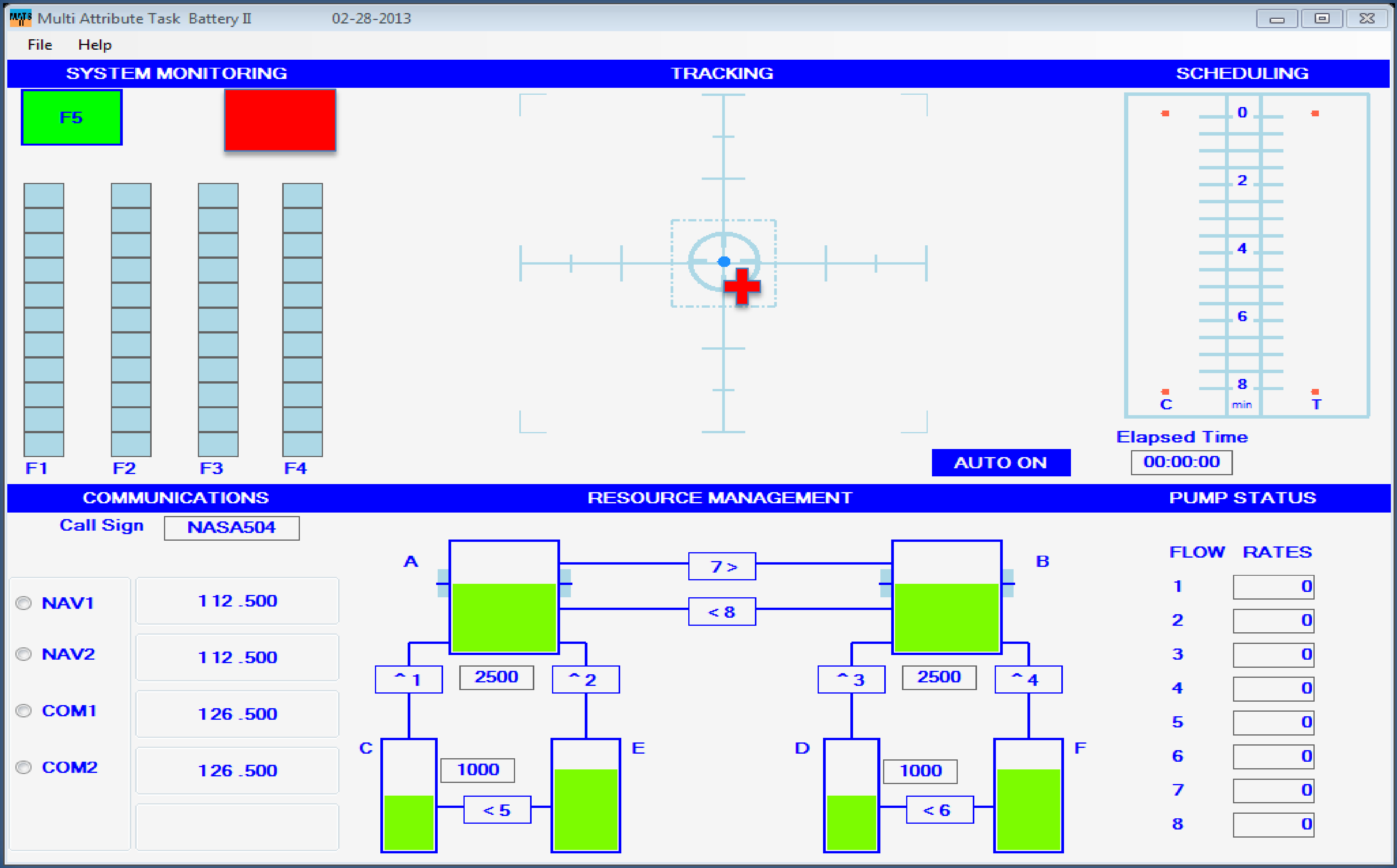
- MATB-II scores while breathing narcotic gases were normalized to baseline

STUDY DESIGN

- Surface Phase
  - With and without exercise
  - PN2: 0.8 and 0
  - PO2: 0.2 and 1.0
  - PCO2: 0 and 7.5%

- Hyperbaric Phase
  - With <u>OR</u> without exercise
  - EAD: 158 or 200 fsw
  - PN2: 4.5 or 5.6
  - PO2: 0.2 and 1.3, or 0.2
  - PCO2: 0 and 7.5%

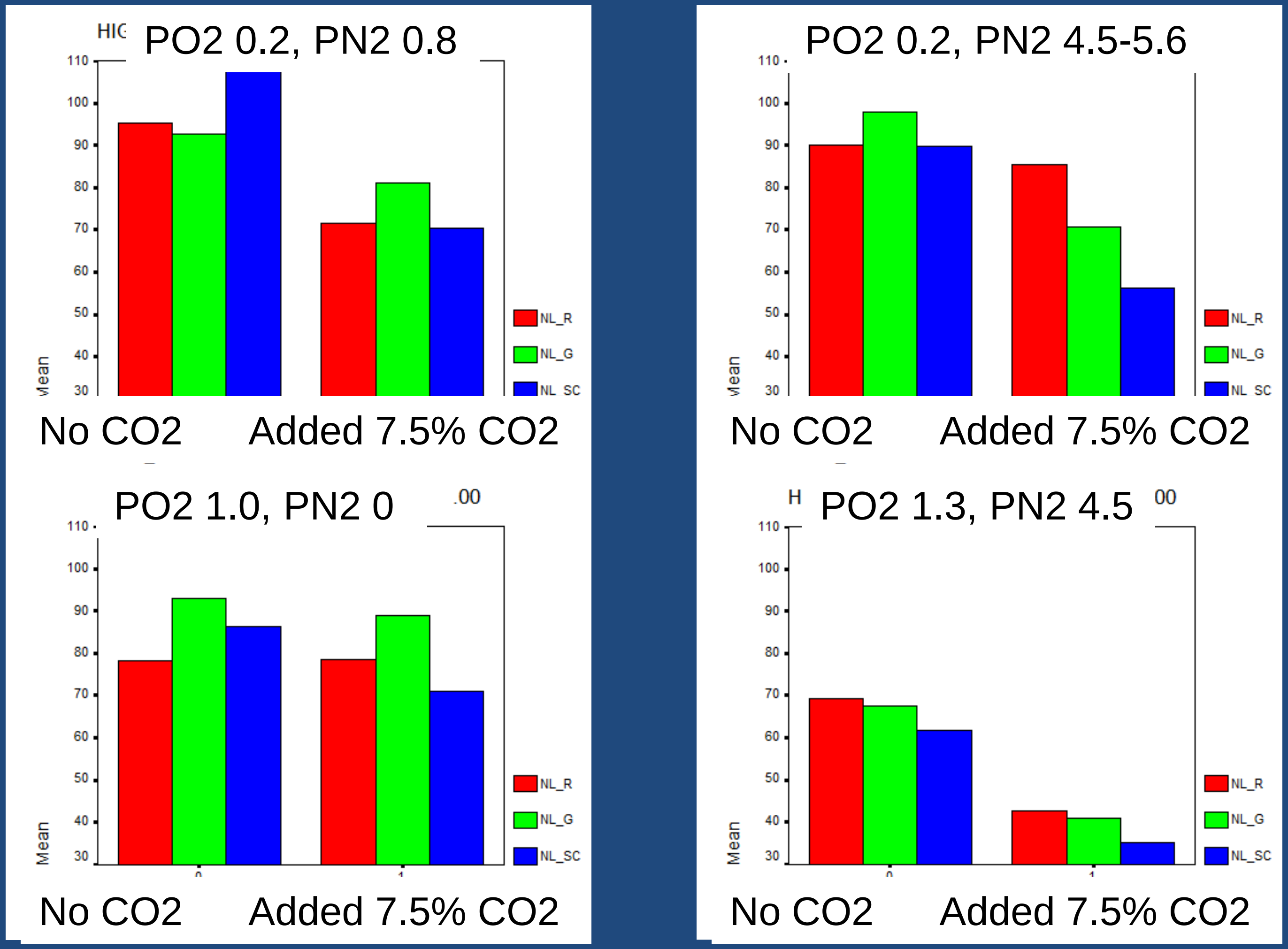
MATB-II



Multi Attribute Task Battery II
02-28-2013
File
Help
SYSTEM MONITORING
TRACKING
SCHEDULING
F5
F1
F2
F3
F4
0
2
4
6
8
C
min
T
Elapsed Time
00:00:00
AUTO ON
COMMUNICATIONS
RESOURCE MANAGEMENT
PUMP STATUS
Call Sign
NASA504
NAV1
112 .500
NAV2
112 .500
COM1
126 .500
COM2
126 .500
A
B
C
D
E
F
7 >
< 8
^ 1
2500
^ 2
^ 3
2500
^ 4
1000
< 5
1000
< 6
FLOW RATES
1 0
2 0
3 0
4 0
5 0
6 0
7 0
8 0

RESULTS

- Elevated PN_2 and PCO_2 decreased overall accuracy for the system-monitoring (SYSMON) attention & surveillance tasks by 30% from baseline (P=<0.001).



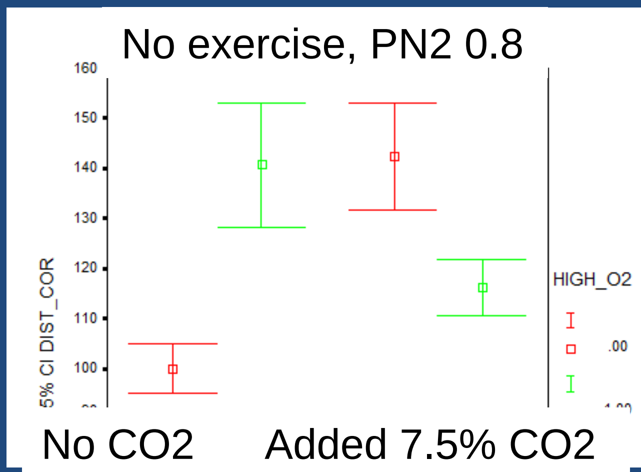
Accuracy of red and green lights (not significant)
Accuracy of scales: (PCO2: p=0.002, PN2: p=0.03, PO2 p=0.01)

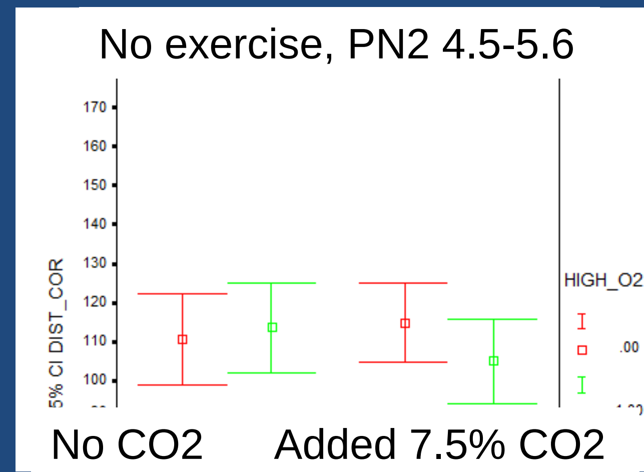
RESULTS

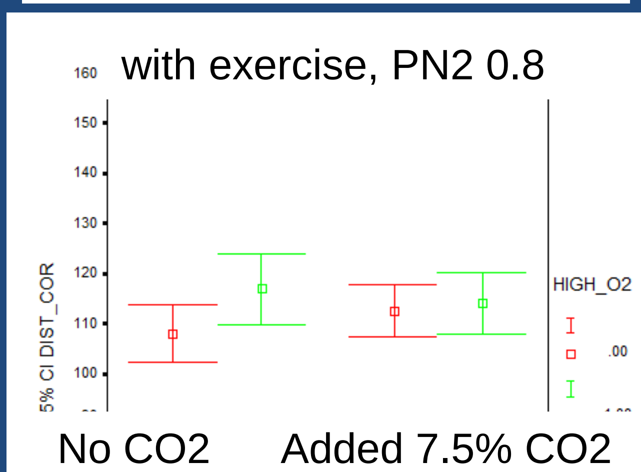
- Tracking task (TRACKING) accuracy at low cognitive workload was not consistently affected by elevated PN_2 or PCO_2 but accuracy decreased at high workloads for both narcotic and non-narcotic gases.
- *Corrected tracking distances by exercise, PN2, PCO2 and PO2:*

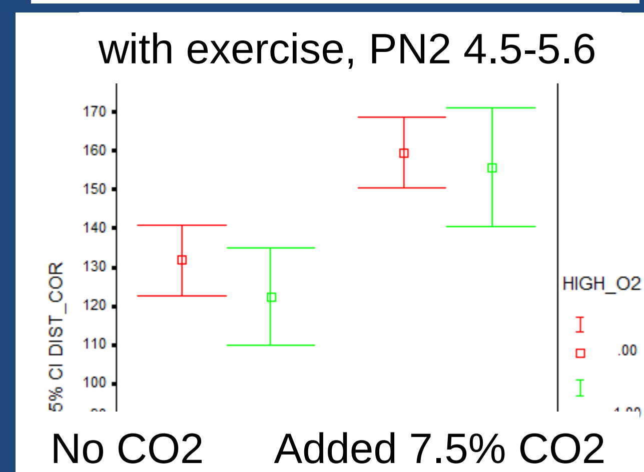
Low O2

High O2





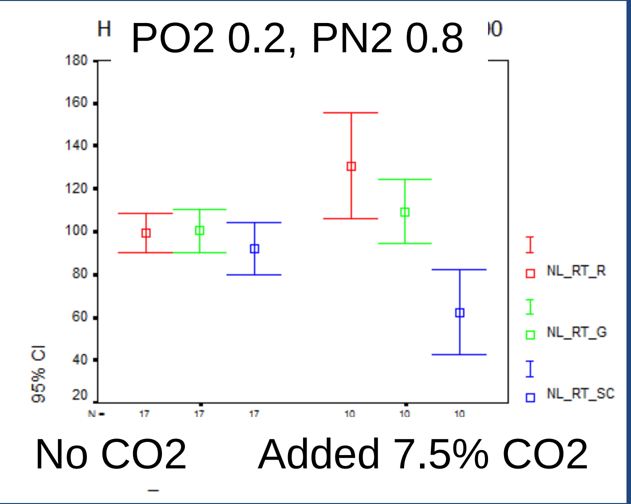


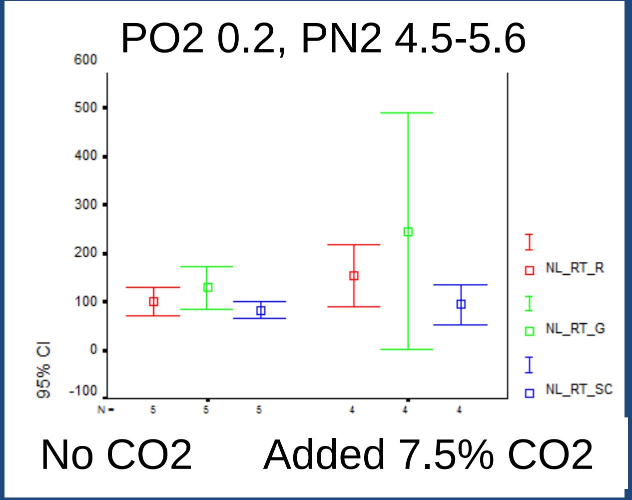


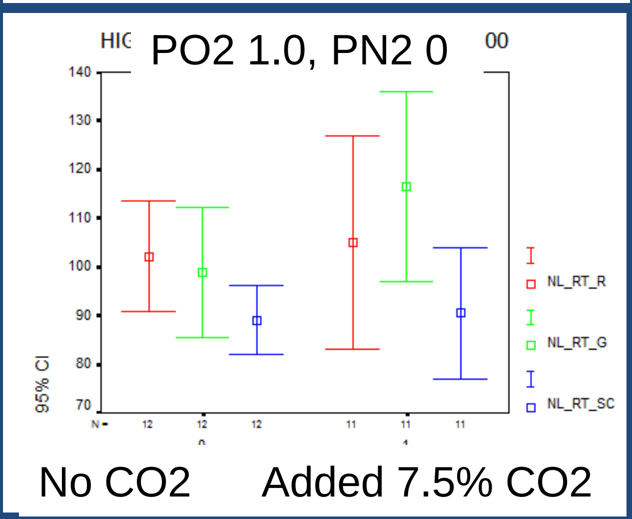
ANOVA p-values: (exercise $p=0.003$, PN2 $p<0.014$, PCO2 $p<0.003$, PO2 $p=0.860$).

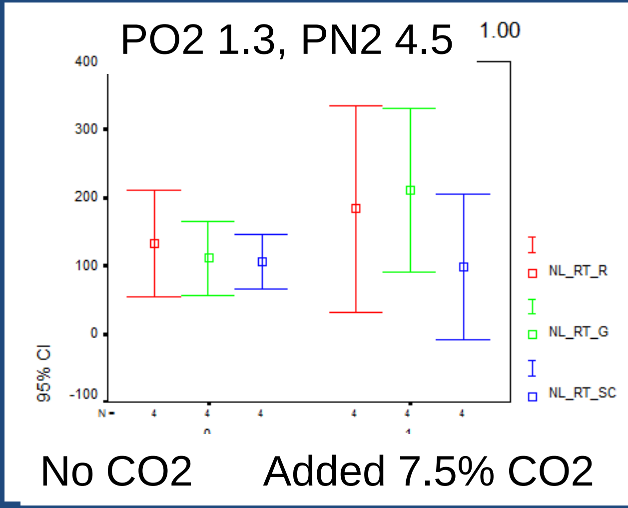
RESULTS

Reaction time for SYSMON tasks for added PCO2 and PN2:









CONCLUSIONS

- The MATB-II is sensitive enough to detect the cognitive effects of breathing narcotic gases.
- Preliminary results indicate that ability to multi-task and pay attention to surroundings is affected by narcotic breathing gases.
- Cognitive performance declines with increased partial pressures of nitrogen, carbon dioxide and oxygen
  - Which is worse, and to what degree is yet to be determined, particularly for oxygen
- Ability to focus on a single task may be less affected depending on overall task loading.

ACKNOWLEDGEMENTS

Funded by NAVSEA Deep Submergence Biomedical Contract #N0463A-12-C-0001.

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