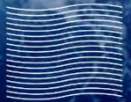# Effects of Environmental Carbon Dioxide on Transcutaneous Carbon Dioxide and Cognitive Function in Submariners

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Disclaimer

- This study is undergoing peer review, and is currently unpublished

Background

- CO2 is a contaminant of interest in Submarines

- In RAN submarines:

  – Monitored through fixed (Drager Polytron 8720) and portable (Drager XAM-8000/Accuro tubes) systems

  – Controlled by

    - Snorting

    - MEA-based Air Purification Unit

    - Sofnalime absorption canisters
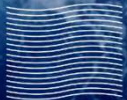
    - Internal ventilation for maximum dilution

Background

- Worksafe Australia Guidelines:
  - 8-hour TWA 0.5%
  - 15-min STEL 3%
- RAN Maximum Permissible Concentration:
  - Normal: < 1%
 - 24hr: 1-2%
  - 1-hr: 2-3%

Background

- Physiological Effects of higher concentration of CO_2 well established
  - 1-3% increased tidal volume and respiration rate
  - 3-5% tachycardia, hypertension
  - 5-8% dizziness, confusion, dyspnoea
- Effects of lower levels less well understood
  - Studies in office environment suggest 0.1-0.25% may affect decision-making
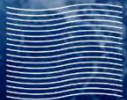 - Unable to be replicated in submariners
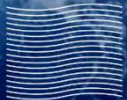
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Background

- Transcutaneous measurement of CO2 first described 1960

- Applying local heat to skin allows capillary CO2 to be similar to arterial

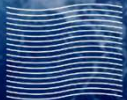- Widely used clinically eg sleep labs

Aim

- To establish whether there is any correlation between inspired and transcutaneous CO_2

- To establish whether there are any significant cognitive effects on submariners from atmospheric CO_2

- In the setting of an operation Australian submarine

Methods

- Conducted during a seagoing period on an operational Collins Class Submarine in 2019
- Atmospheric CO_2 continuously measured and logged by submarine systems
- Submarine conducted normal procedures to maintain atmosphere within prescribed limits
- 9 volunteers took turns wearing a Sentec Transcutaneous V-sign monitor
  - Each volunteer wore the sensor for between one and three 3 watchkeeping periods
  - Place just below mid clavicle
  - Participants conducted normal seated duties whilst wearing sensor, eg operating sonar/combat system or platform systems.
 - Monitor continuously recorded $PtcCO_2$ and pulse oximetry
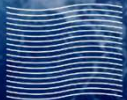
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Methods

- 9 additional volunteers underwent psychometric testing using PhysioPad:
  - Adaptive Visual Analogue Scale fatigue test
  - Simple Math Process
  - Perceptual Vigilance Task
  - Time Estimations Task (Time Wall)
  - Pursuit Rotor Test
- Participants initially familiarised with software prior to sailing
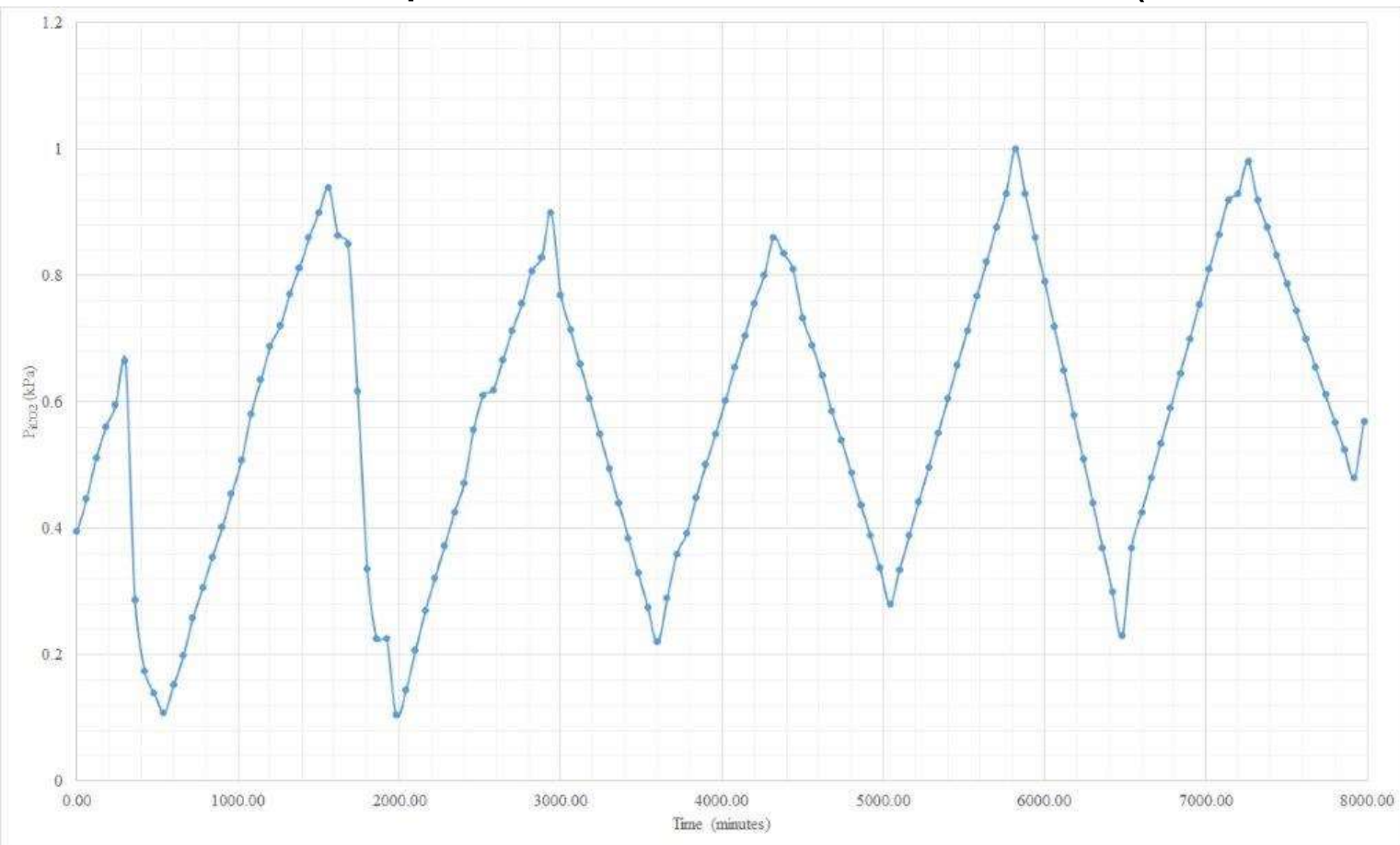- Typically conducted the tests just prior to going on watch and on completion of their watch
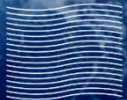
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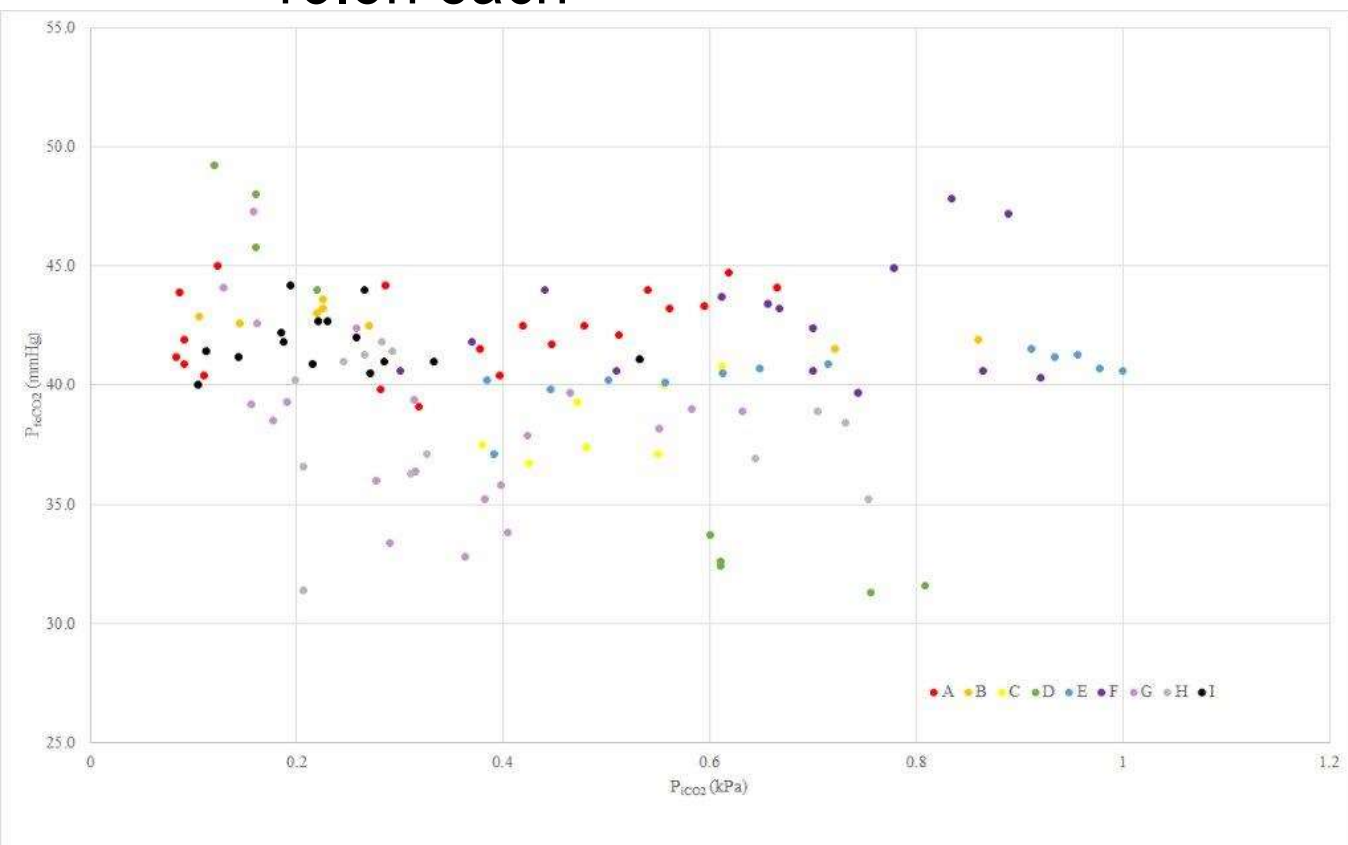RESPECT
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Results

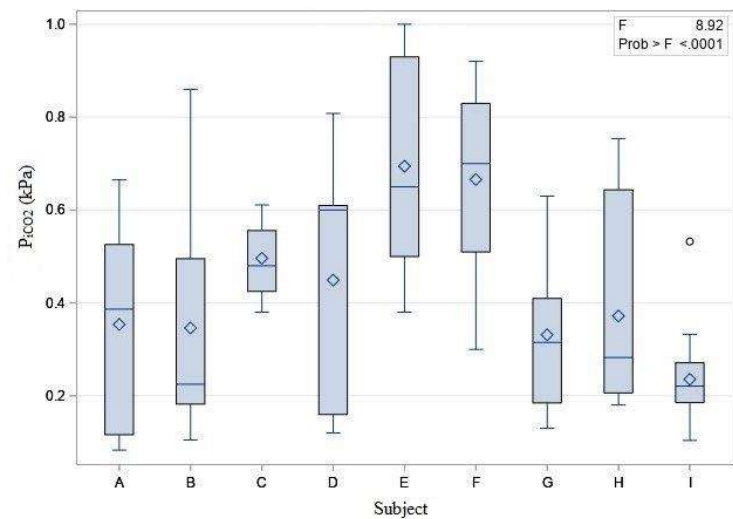- Atmospheric CO2 was 0.22-1.00% (mean 0.59% SD 0.29%)
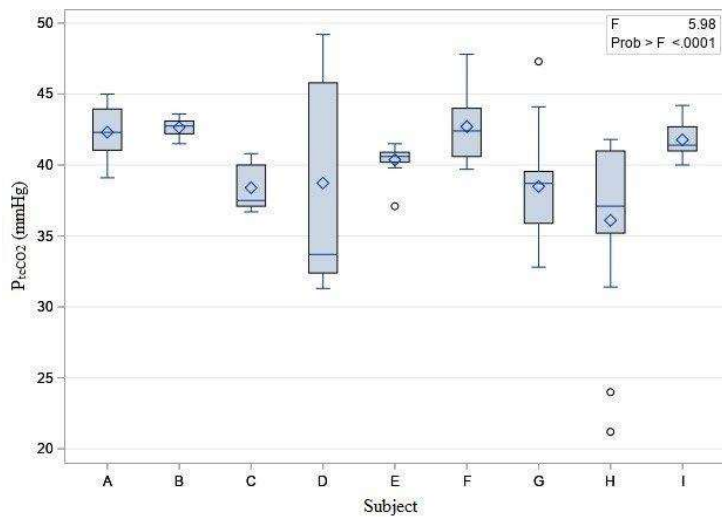
Results

- 9 subjects recorded a cumulative 122h of PtcCO2 data (mean 13.5h each

Results

- Pearson correlations varied significantly by individual subject
- Overall correlation was 0.01 (P=0.87)

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Results – Cognitive Tests

- 9 participants completed total 95 cognitive testing sessions

Psychometric test	Parametric		Non-parametric	
	rho	P-value	rho	P-value
AVAS1 - (Confused to Clear headed)	0.03	0.81	-0.07	0.55
AVAS2 - (Well-coordinated to Clumsy)	-0.20	0.11	0.19	0.14
AVAS3 - (Mentally slow to Clear headed)	0.22	0.06	-0.14	0.23
AVAS4 - (Attention-focussed to Dreamy)	-0.00	0.98	-0.09	0.49
AVAS5 - (Happy to Sad)	-0.05	0.69	-0.04	0.74
AVAS6 - (Interested to Bored)	-0.07	0.59	0.08	0.53
AVAS7 - (Nauseated-Queasy to Not nauseated)	-0.04	0.79	0.01	0.96
AVAS8 - (No fatigue to Fatigue)	-0.25	0.03	0.25	0.04
T3 - (Simple Math Process)	0.01	0.94	0.03	0.78
T4 - (Perceptual Vigilance Task)	0.24	0.03	0.24	0.04
T5 - (Time Estimation Task)	0.20	0.09	-0.10	0.37
T6 - (Pursuit Rotor Test)	-0.06	0.58	0.01	0.93

Results – Cognitive Tests

Discussion

- Observed no association between inspired and transcutaneous CO_2 in these circumstances
    - Some variation noted between subjected
    - Consistent with normal respiratory function maintaining homeostasis
- Inspired CO_2 not observed to have any effect on cognitive performance in a real-world environment
    - Many other confounding factors in a complex submarine environment
        - Eg sleep, stress, workload.
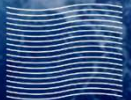
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Discussion

- Results consistent with other lab-based assessments of CO_2 effect on submariners (eg Rhodeheffer et al 2018)

- Not consistent with Satish et al 2012,2015) who found measurable cognitive impairment at $FiCO_2$ as little as 0.25%
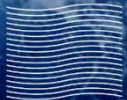
- Possible "adaption" mechanism seen in submariners?

Conclusion

Within the range of environmental CO_2 concentration found in Australian submarines, there was no statistically significant association found between $PiCO_2$ and $PtcCO_2$.

Similarly, there was no statistically significant association between $PiCO_2$ and cognitive function identified

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