A NOVEL METHOD OF STRESS MEASUREMENT BASED ON THERMODYNAMICS

RESULTS FROM THE CHILL-ICE II SPACE ANALOG MISSION

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Picture Source: CHILL-ICE II / ICEE.Space

Key takeaways

- Stress entropic load (SEL) generally increased in AAs and decreased in AA backups
- Reaction time worsened in 2 AAs (out of 3), and slightly improved in AA backups over the course of mission
- Alpha had the most consistent RT, SEL, and low laps probability.

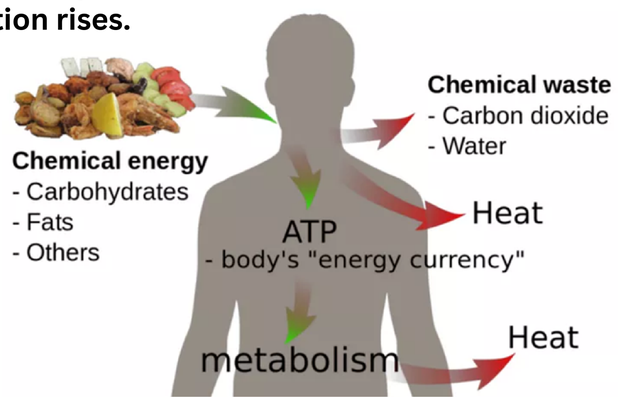
Objectives

- **measure** physiological markers of **stress** reaction and **cognitive performance** in 7-day lunar analogue mission
- **validate** feasibility of **Entrant prototype for** cave-based **space analog missions**

Background

The ability to detect inadequate stress reaction and predict human failure has utmost importance in spaceflight. Until now, **we lacked methods to measure stress reaction objectively, sensitively, and in real time.**

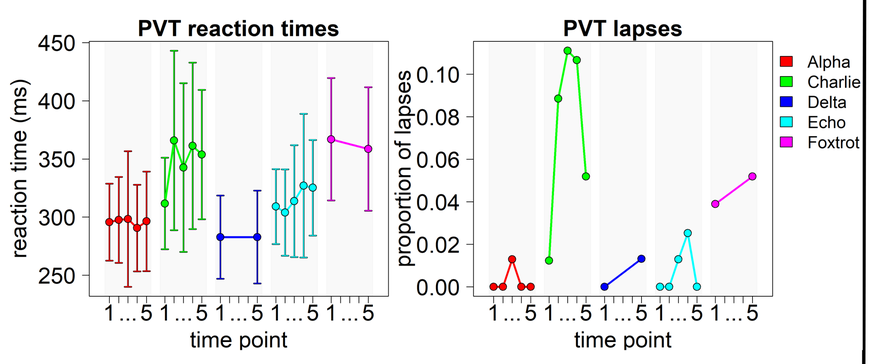
The Stress Entropic Load (SEL) [1] is a novel model based on thermodynamic modelling of entropy change between human and their surroundings. It **quantifies the accumulation of entropy produced by individual in a time interval**. The assumption is that **with more stress the need for adaptation increases and in result the entropy production rises.**



Unlike interviews, questionnaires or other indirect physiology markers of stress reaction (such as hormones, cardiovascular markers, galvanic skin response, etc.), **SEL allows to calculate and compare stress reaction across individuals and contexts objectively** and may be more sensitive to cognitive decrements [1].

Results

1) Reaction time and lapse probability. In two AAs we found increase of reaction time across the measurements and increase of laps probability during the mission in cave. One AA (Alpha) had most stable and less error prone performance. In AA backups, the probability of error increased.

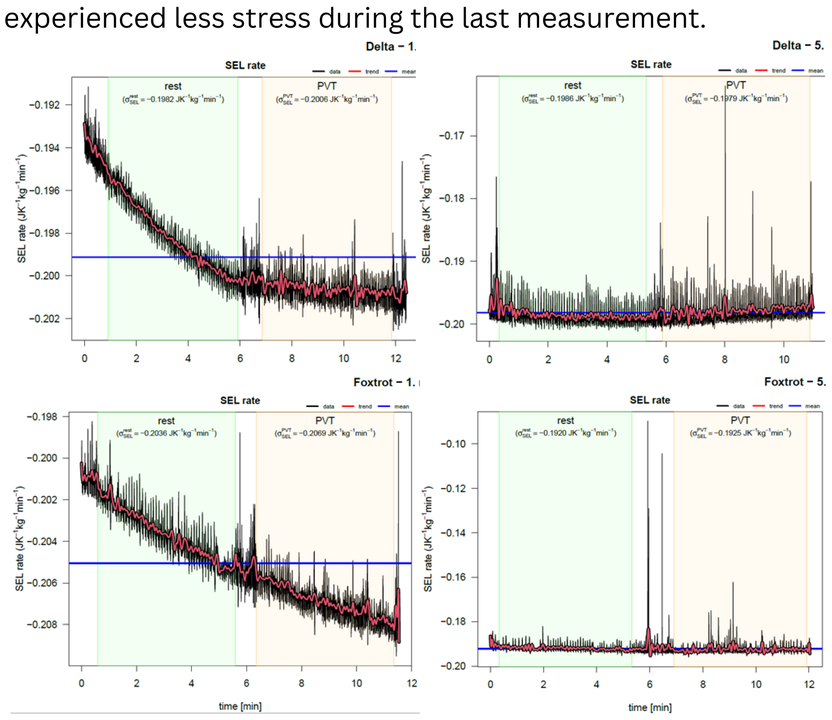


2) Mean SEL and HRV values during resting, PVT and combined. The table shows mean values of the SEL rate and of the root mean square of successsive differences between heartbeats (rMSSD). Lower values for SEL and higher values for rMSSD indicate lower physiological stress. Trends are collored accordingly. Overall, the trend seem to be comparable in half of the measurements. Differences can be seen in Echo, Delta and Foxtrot values. This might be caused by the influence of other physiologcal processes on rMSSD. Further research is needed to properly address differences in indicative value of both methods for physiological stress.

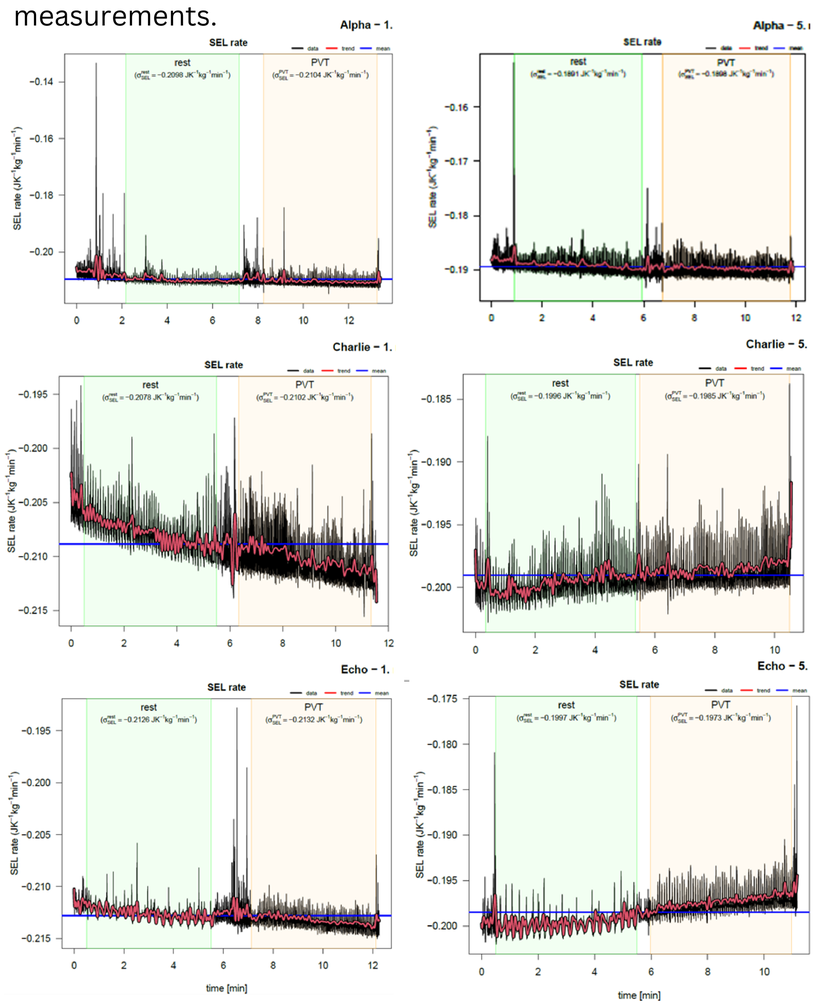
		SEL rate ($JK^{-1}kg^{-1}min^{-1}$)			rMSSD		
	meas.	rest	PVT	Combined	rest	PVT	Combined
Alpha	1	-0,210	-0,210	-0,210	87,41	77,28	83,08
	5	-0,189	-0,190	-0,189	39,43	32,01	34,98
Charlie	1	-0,208	-0,210	-0,209	52,94	59,74	59,52
	5	-0,200	-0,199	-0,199	27,20	23,90	25,66
Echo	1	-0,213	-0,213	-0,213	97,47	28,39	69,09
	5	-0,200	-0,197	-0,199	57,94	34,55	48,27
Delta	1	-0,198	-0,201	-0,199	72,95	35,13	87,99
	5	-0,199	-0,198	-0,198	22,07	25,12	23,64
Foxtrot	1	-0,204	-0,207	-0,205	55,58	65,65	59,50
	5	-0,192	-0,193	-0,192	64,40	61,30	61,47

Due to fragmentary data from the cave phase, we show only first and last measurement.

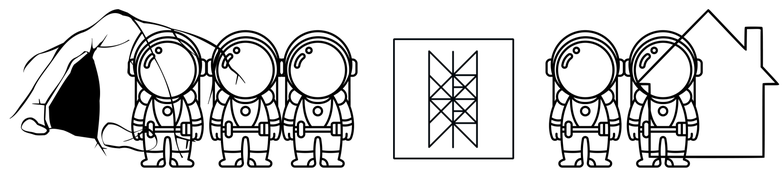
3) SEL production in AA backups. During first measurement, both exhibited notable decrease of SEL production, while final measurement was more linear. It is possible that the last day their ability to rest effectively decreased or that they experienced less stress during the last measurement.



4) SEL production in AAs. In two AAs the trend changed from decrease of SEL production in first measurement to increased. One AA (Alpha) exhibited linear trend in both measurements.



Methods



Participants: 3 AAs (1F) and 2 AA backups (2F).
SEL: prototype by Entrant s.r.o.
Resting phase: 5-minute sitting, focusing on breath.
Reaction time: 5-minute PVT.
RT > 100 and < 500 is valid. RT > 500ms is a lapse.
Measurement timing: 1h after waking up, on empty stomach, before increased physical activity.

Meas.	1			2		3		4		5
day	20	21	22	23	24	25	26	27	28	29	30

CHILL ICE II mission

Organizer: ICEE.Space.
Location: 135m deep in the lava tube of Surtshellir, Iceland.
Duration: 7 days (6 nights, 148h).
Type of analogue: Moon.

Two of the AAs on the EVA in front of the habitat. Source: CHILL-ICE II / ICEE.Space

INVESTORS WANTED!

The prototype for SEL measurement **was succesfully tested in Antarctic** mission 2022. This project aimed to **validate it's use in space analogue missions** to measure stress reaction in analogue astronauts (AAs).

Entrant s.r.o. wants to **upscale the prototype** for use in underwater and hyperbaric conditions.

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Lucie Ráčková wearing the prototype of SEL measurement device by Entrant s.r.o. during an Antarctic research expedition in 2022. Credit: Vendula Koublová

ENTRANT website **Personal LinkedIn** **IG profile**

References

[1] Zlámal, F., Lenart, P., Kuruczová, D., Kalina, T., de la Torre, G., Ramallo, M.A. and Bienertová-Vašků, J., 2018. Stress entropic load: New stress measurement method? PloS ONE, 13(10), p.e0205812.

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