Introduction: Nearly all living organisms evolved circadian rhythms as synchronization to rotational movement of the Earth. Lunares habitat is a biological clock laboratory established in 2017 in Poland. The facility is designed to investigate optimal for physiology and health lighting conditions for future Moon and Mars human space missions. Within two-week analog simulations astronaut crews, insects, plants and algae undergo multiple experiments in fully isolated from natural sunlight and UTC time environment. A prototype of physiological lighting administrated inside the habitat activates or inhibits multiple types of photoactive proteins responsible for homeostatic regulatory pathways including nervous, endocrine, digestive and immune systems in humans as well as growth and development processes in insects and plants. The habitat is additionally equipped with programmed LED lighting system to simulate dawns and dusks (Fig. 1).

Fig. 1. Non-invasive lighting studies in the Lunares habitat. RGB lighting simulates dawns and dusks (graphics: [1]). Prototypes of physiological lamps (right) synchronise biological clock of astronauts (photo: M. Słonina, modified by A. Kołodziejczyk).

Biological clock experiments: During each of three organized analog simulations in 2017, circadian rhythms of 6 analog astronauts with independent control groups were monitored for one month starting one week before the mission, during the mission and 1 week after the mission. 5 subjects underwent the procedure: 12 analog astronauts and 13 control group (without time shifts). Analog astronauts were exposed to time illusions through three different tools used by mission control center: specially adjusted scheduling with only two reference time points for briefings and debriefings, running the whole schedule on the lunar or martian clocks and light control in the habitat. After two days of the mission, astronauts completely lost perception of time. Jet lag was detected by analog astronauts at phase III. Interestingly, phase II was not considered as shifted in time.

During stay in the habitat, analog astronauts were exposed to 4 following circadian phases (Fig.2): first 3 days were 24h, next 4 days 26h (8h advance shift in total), next 4 days 22h (8h delay shift in total), and finally 3 days 24h before end of the mission. Jet lag effects were analyzed including levels of stress, water consumption, urine production and motivation. 5 subjects underwent the procedure: 12 analog astronauts and 13 control group (without time shifts). Analog astronauts were exposed to time illusions through three different tools used by mission control center: specially adjusted scheduling with only two reference time points for briefings and debriefings, running the whole schedule on the lunar or martian clocks and light control in the habitat. After two days of the mission, astronauts completely lost perception of time. Jet lag was detected by analog astronauts at phase III. Interestingly, phase II was not considered as shifted in time.

Fig. 3. Analog astronauts displayed modified water metabolism after changes in their circadian rhythms. Significant changes were observed for urination.
Based on received data, astronauts’ stress and motivation levels were evaluated to be decreased at the Phase III and slightly recovered at Phase IV. Water consumption and urination was changed with changing circadian phases (Fig.3). More studies need to be done to better understand this processes.

**Subjective Time Perception:** The second parameter analyzed during analog simulations was subjective time perception in astronauts and control groups [3]. Data were collected using STPA software written by Matt Harasymczuk (direct link to the application attached below). Subjects were performing the test twice a day just after waking up and just before going to sleep. During the mission subjects were able to see their results and based on them improve their performance. Effect of training was observed in both analog astronauts groups as well as in controls, what means that subjective time perception is related with memory and learning neuronal circuits (Fig.4,5).

**Fig.4.** Subjective time perception experiment used application computing time, regularity and tempo of 5s intervals of clicks (left). One month experiment was divided into two parts: with feedback during the mission and without showing perception results for subjects 1 week before and 1 week after the mission (center).

**Fig.5.** Significant effect of training was observed for both experimental (6 analog astronauts of the CREW) and control groups (MCC 3 - 3 volunteers from the mission control center).
