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**Introduction**

Homeostasis is a self-regulating process that all humans have, it is a process that maintain internal processes and environments at a stable set-points. A concrete of homeostasis is how the body maintains a stable internal temperature of around 37 degrees Celsius, if the temperature raises the body cools itself and vice versa.

investigations have also shown that one of such homeostatic processes are the circadian rhythm, which is a 24-hour cycle of many different processes. Most humans do for instance follow such a circadian rhythm when it comes to the sleep-wake cycle, research has however found that for instance different hormones e.g. (melatonin, cortisol etc.) also follow a similar pattern in 24 hours (Kim et al., 2015). It has also been hypothesized that other human experiences follow a circadian rhythm (McClung, 2013).

This pattern of homeostasis and circadian rhythms can be investigated by a sinusoidal wave as this function has the property of oscillating.

Equation (1)

**hypothesis**

Tiredness, mood and hunger would follow an oscillating pattern best described by a sinusoidal function with an oscillation time of one day e.g. a frequency of 1/24 hours.

**Methods**

Using an experience sampling paradigm, student of the masters of cognitive science was promoted Between the 8th of September and the 21st  of November Students were prompted by the teacher and answered the prompts to the best of their abilities at the given time and were also encouraged to fill the questionnaires without being prompted.

**Prompts.**

When prompted students were instructed answer the questions which can be seen in appendix A. For the following paper the students’ tiredness/freshness and hunger scores were investigated which was given by a score of 0 to 100.

**Statistical analysis**

All code to reproduce the following results can be found in appendix C.   
To investigate the hypothesis two different models were fitted. First, a non-linear mixed effects model was fitted, where the amplitude the intercept and the phase of the sinusoidal wave could vary and the frequency was set to 1/24 hours (eq. 1), next we fitted a linear mixed effects model where we kept the frequency constant to 1/24 hours. The random effects for each model were subject ids, for the non-linear model only the intercept was set to vary for each participant. All participants with less than 10 answered prompts were excluded from the analysis, and analysis on mood and hunger was only calculated by the non-linear model

The linear mixed effects model was parameterized in the following way:

This parameterization implies that the amplitude of the model and the phase can be determined from the two beta estimates in the following way, for derivation see appendix B, furthermore the uncertainties on these can be determined using error propagation see appendix C.

**Results**

The linear mixed effects model investigating freshness showed a significant intercept ( = 45.6 se = 2.9 t = 15.8 p < .0001 and that both beta estimates were statically significant , se = 1.6 t = -11 p< .0001, , se = 2.3 t = -6.1 p< .0001. Recalculating this to the amplitude we get A = and 1.1

Results from the non-linear mixed effects model on freshness showed A = 20.75 se = 1.9 t = 11.2 p<.0001 se = 0.07 t = 61.4 p<.0001 and k = 42.3 se = 2.2 t = 18.7 p<.0001.

Chart

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Figure 1: Displays the results of the three non linear mixed effects models for freshness, hunger and mood for each participant.

Results from the non-linear mixed effects model on mood showed A = 4.8 se = 1.5 t = 3.3 p<.005 se = 0.25 t = 13.4 p<.0001 and k = 66 se = 2.8 t = 23.3 p<.0001.

Results from the non-linear mixed effects model on hunger showed A = 7.4 se = 1.9 t = 3.9 p<.0001 se = 0.36 t = 5.7 p<.0001 and k = 61 se = 2.6 t = 23.5 p<.0001.

**Discussion**

The results of the current study suggest that the freshness of students can be explained with a sinusoidal function where the oscillation time of the wave is set to 24 hours. These results therefore support the idea that freshness follows a circadian rhythm. The results also showed that hunger and mood followed a similar pattern however not to the same degree as with freshness.

**Limitations**

Big limitations of the current study come from the low participation rate of students, but especially also the low number of answered prompts in the time interval from midnight to 6 in the morning. This is most likely because people slept at this time, however inference is especially difficult to make with one fourth of the time missing. Due to the low sample size a nonlinear mixed effects model where the frequency of the oscillation wasn’t feasible, which could have further strengthened the hypothesis that these experiences follow a 24-hour cycle.

Appendix A:

To see the questions the students were prompted by follow the following link to try the questionnaire itself:

<https://chani.cogsciexperiment.au.dk/BodyFeelingExp.html?fbclid=IwAR175uXWlcbLCOH9zS-L0wrY51ca8B2UOkG8CNCAZESOXjLoWgH1nTUP_e8>

appendix B:

deviation of phi.

Deviation of the amplitude

Appendix C

All code can be found on the following GitHub:

<https://github.com/JesperFischer/MEG_ADV_cognitive_neuro/tree/master/Homeostasis>

**Literature:**

Kim, T. W., Jeong, J.-H., & Hong, S.-C. (2015). The Impact of Sleep and Circadian Disturbance on Hormones and Metabolism. *International Journal of Endocrinology*, *2015*, 591729. <https://doi.org/10.1155/2015/591729>

McClung, C. A. (2013). How might circadian rhythms control mood? Let me count the ways….. *Biological Psychiatry*, *74*(4), 242–249. <https://doi.org/10.1016/j.biopsych.2013.02.019>