Neuro-metabolic pathways linking high protein meal reducing food craving

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Background

Across species, ***high protein*** food has been shown to regulate ***appetite and satiety***[1]. Protein intake is assumed to increase plasma tyrosine levels[2], which in turn increase ***tyrosine*** availability for uptake into the brain. Tyrosine serves a precursor for dopamine synthesis[2], controlling for food intake. However, the ***neural metabolic mechanism*** underlying the protein meal in reducing appetite and food intake remains unclear.

Research questions

- RQ1: Does a high protein breakfast decrease food craving through tyrosine dynamics?
- RQ2: Does a high protein breakfast modulate dopamine-related brain function?
- RQ3: Does a high protein breakfast require smaller or larger reconfigurations in the gradient space of brain organization?

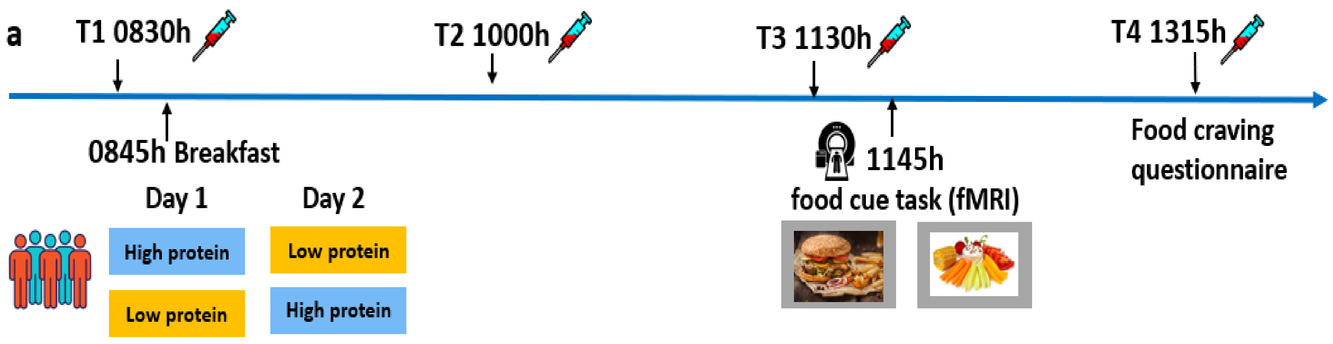
Methods

Participants

30 male participants (age, mean ±SD, 23.63 ±3.23 years; BMI, mean ±SD, 22.90±1.80 kg/m^2)

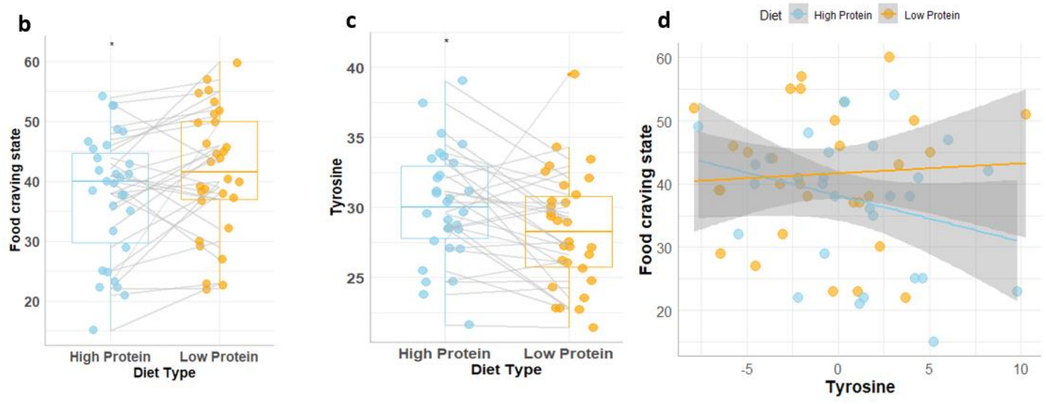
Task and Procedure

- Randomized, counterbalanced, within-subject design: high protein (25% proteins, 50% carb, and 25% fats) vs. low protein (10% proteins, 80% carb, and 10% fats);
- German version of state food craving questionnaire[3]
- Food cue task under fMRI: high caloric vs. low caloric food stimuli



Results

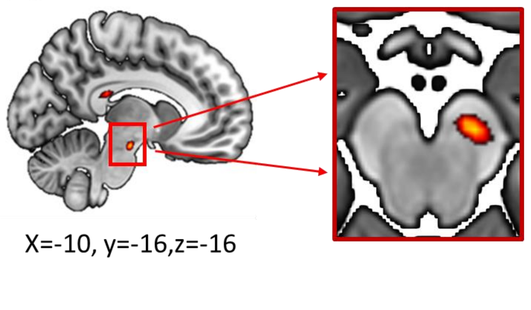
RQ1 Does a high protein breakfast decrease food craving through tyrosine dynamics?



- High protein breakfast decreased food craving (**b:** t (29) = 2.40, p = 0.02) and increased plasma tyrosine concentration **(c:** t=-2.29, p = 0.02**).**
- Tyrosine predicted lower food craving after eating high protein breakfast (**d:** linear mixed-effect model, breakfast type x tyrosine: β = -1.05, SE= 0.40, p = 0.03).

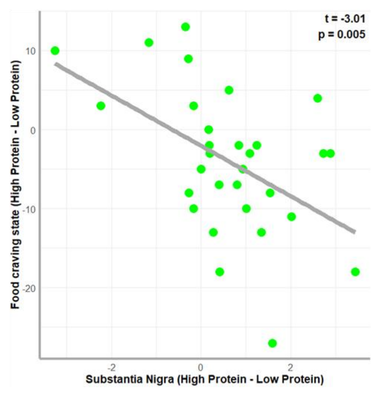
RQ2 Does a high protein breakfast modulate dopamine-related brain function?

a Substantia Nigra (High Protein vs Low Protein)



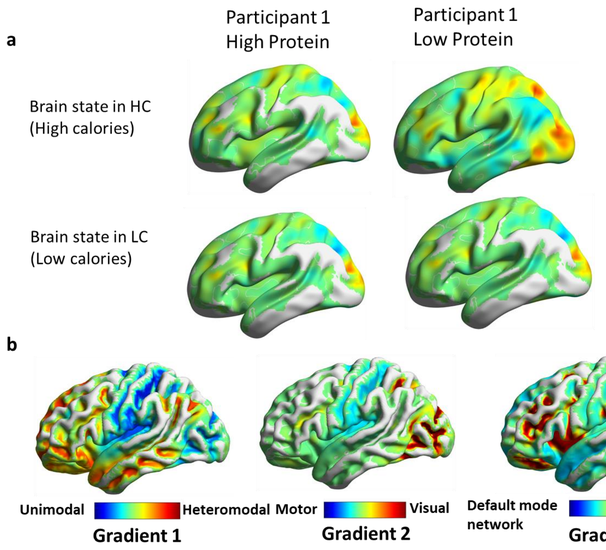
X=-10, y=-16,z=-16

b



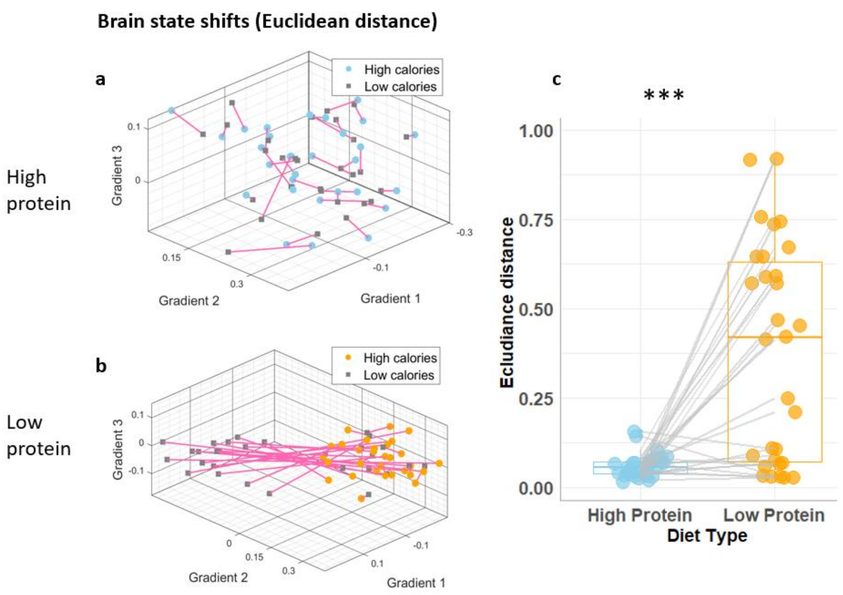
- Contrast: high protein $_{\text{(high vs low caloric)}}$ > low protein $_{\text{(high vs low caloric)}}$; FWE corrected cluster-wise threshold p < 0.05.
- There was a significantly stronger substantia nigra (SN) activity after eating high protein breakfast **(a),** which predicted the reduction of food craving **(b).**

RQ3 Does a high protein breakfast require smaller or larger reconfigurations in the gradient space of brain organization?



a. Whole brain activation brain maps corresponding to high and low caloric food stimuli , representing condition specific ***brain states.***

b. The three principal axes of hierarchical brain organization[4]



a and b: ***Brain state shifts*** in the high and low protein breakfast sessions.

c. Euclidean distance (ED): high protein < low protein: Wilcoxon test, W=420, Z=3.86, p < 0.001.

Conclusions

- High protein meal decreases food craving through increased tyrosine levels.
- High protein meal recruits midbrain activations, which predict food craving.
- high protein meal requires smaller shifts in brain states along spatial gradients.

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References

1. Kohanmoo, A., Faghih, S., & Akhlaghi, M. (2020). Effect of short- and long-term protein consumption on appetite and appetite-regulating gastrointestinal hormones, a systematic review and meta-analysis of randomized controlled trials. Physiology and Behavior, 226(August), 113123.
2. Wurtman, R. J., Wurtman, J. J., Regan, M. M., Mcdermott, J. M., Tsay, R. H., & Breu, J. J. (2003). *Effects of normal meals rich in carbohydrates or proteins on plasma tryptophan and tyrosine ratios 1 – 3*. 128–132
3. Meule, A., Lutz, A., Vögele, C., & Kübler, A. (2012). Food cravings discriminate differentially between successful and unsuccessful dieters and non-dieters. Validation of the Food Cravings Questionnaires in German. *Appetite*, *58*(1), 88–97
4. Margulies, D. S., Ghosh, S. S., Goulas, A., Falkiewicz, M., Huntenburg, J. M., Langs, G., Bezgin, G., Eickhoff, S. B., Castellanos, F. X., Petrides, M., Jefferies, E., & Smallwood, J. (2016). Situating the default-mode network along a principal gradient of macroscale cortical organization. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(44), 12574–12579.

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