Modelling homeostatic influences on human risky choice

Steven Geysen (sgeysen@uni-koeln.de)
Biological Psychology, Department of Psychology,
University of Cologne, Germany

Angela M. Brands (abrands1@uni-koeln.de)
Biological Psychology, Department of Psychology,
University of Cologne, Germany

Heidrun Schultz (heidrun.schultz@cbs.mpg.de)
Chair of Lifespan Developmental Neuroscience,
TUD Dresden University of Technology, Germany

Julian König (julian.koenig@uk-koeln.de)
Clinic and Polyclinic for Child and Adolescent Psychiatry, Psychosomatics and Psychotherapy,
University Hospital Cologne, Germany

Marc Tittgemeyer (tittgemeyer@sf.mpg.de)
Translational Neurocircuitry, Max Planck Institute for Metabolism Research, Germany
Excellence Cluster on Cellular Stress Responses in Aging Associated Diseases (CECAD),
University of Cologne, Germany
Faculty of Medicine, University of Cologne, Germany

Jan Peters (jan.peters@uni-koeln.de)
Biological Psychology, Department of Psychology, University of Cologne, Germany

Abstract

Decision-making is often thought to be under homeostatic control. However, evidence remains mixed and the underlying mechanisms are unclear. One potential mechanism that might drive changes in decision-making may be the hunger hormone ghrelin, which interacts with the dopaminergic system. In two separate studies, we examined the effects of manipulating ghrelin levels on human risky choice in healthy male participants, either via a brief fasting period (study 1, N=37) or one night of total sleep deprivation (study 2, N=40). We found no credible effect of the experimental manipulations on the proportion of risky choices. Computational modelling did not reveal consistent effects of homeostatic manipulations on model parameters. Including manipulation-induced changes in ghrelin levels in the model reveal no robust associations. FMRI analyses did not reveal homeostatic effects on neural signatures of subjective value or choice. Our results suggest that homeostatic influences in risky decision-making may be weaker than previously thought.

Keywords: decision-making; fMRI; hierarchical Bayesian modelling; hunger; probability discounting; sleep deprivation

Introduction

In order to make informed decisions, it is important to accurately process the uncertainty and risk associated with each option (Fox & Poldrack, 2009; Morelli et al., 2022). Different homeostatic states may affect the decisions people make during everyday life. One potential factor that may mediate the effects of homeostatic states on risky choice behaviour is ghrelin, a central hormone at play in modulating states of hunger (Müller et al., 2015). Ghrelin levels increase in preparation of food and following sleep deprivation (Cummings et al., 2001; Taheri et al., 2004). Ghrelin interacts with the hypothalamus via the vagus nerve (Wren et al., 2000), and is found to induce dopaminergic activity in the ventral tegmental area (VTA) and nucleus accumbens (NAc; Abizaid et al., 2006).

The predicted role of ghrelin on risky choice behaviour is supported by the observation that participants with higher ghrelin levels scored higher on reward sensitivity and lower on punishment sensitivity (Ralevski et al., 2018). Moreover, participants may make riskier choices when hungry (Levy et al., 2013) or when sleep deprived (Brunet et al., 2020; Venkatraman et al., 2007). Conversely, they may act more risk averse shortly after a meal (Symmonds et al., 2010).

Methods

To study risky decision-making, participants performed a variant of the probability discounting task (Figure 1.A). In each trail, participants had to choose between a safe option (€20 guaranteed) or a risky option of which the reward magnitude ranged between €20.50 and €80 and its probability ranged between 0.17 and 0.99. The fMRI data was collected in a 3T whole-body scanner.

Male participants performed the task three times (each session was separated by one week): one behavioural pretest and two counterbalanced experimental sessions. We manipulated ghrelin levels with two different types which proved to be effective in previous studies: hunger and sleep-deprivation. Study 1 (N=37) had a within-subject design where participants were either sated (SAT; 2 hours and 52 ($\pm$ 68) minutes since last meal) or hungry (FAS; 8 hours and 19 ($\pm$ 28) minutes since last meal) during the experimental sessions. Study 2 (N=40) had a within-subject design where participants performed after one night of normal sleep (NNS; 6 hours and 44 ($\pm$ 56) minutes) or after a night of total sleep deprivation (TSD). In both studies, we collected blood samples during the experimental sessions, right before participants entered the MRI scanner to start the task, to measure participants' ghrelin, leptin, insulin, cortisol, and glucose levels.

Results

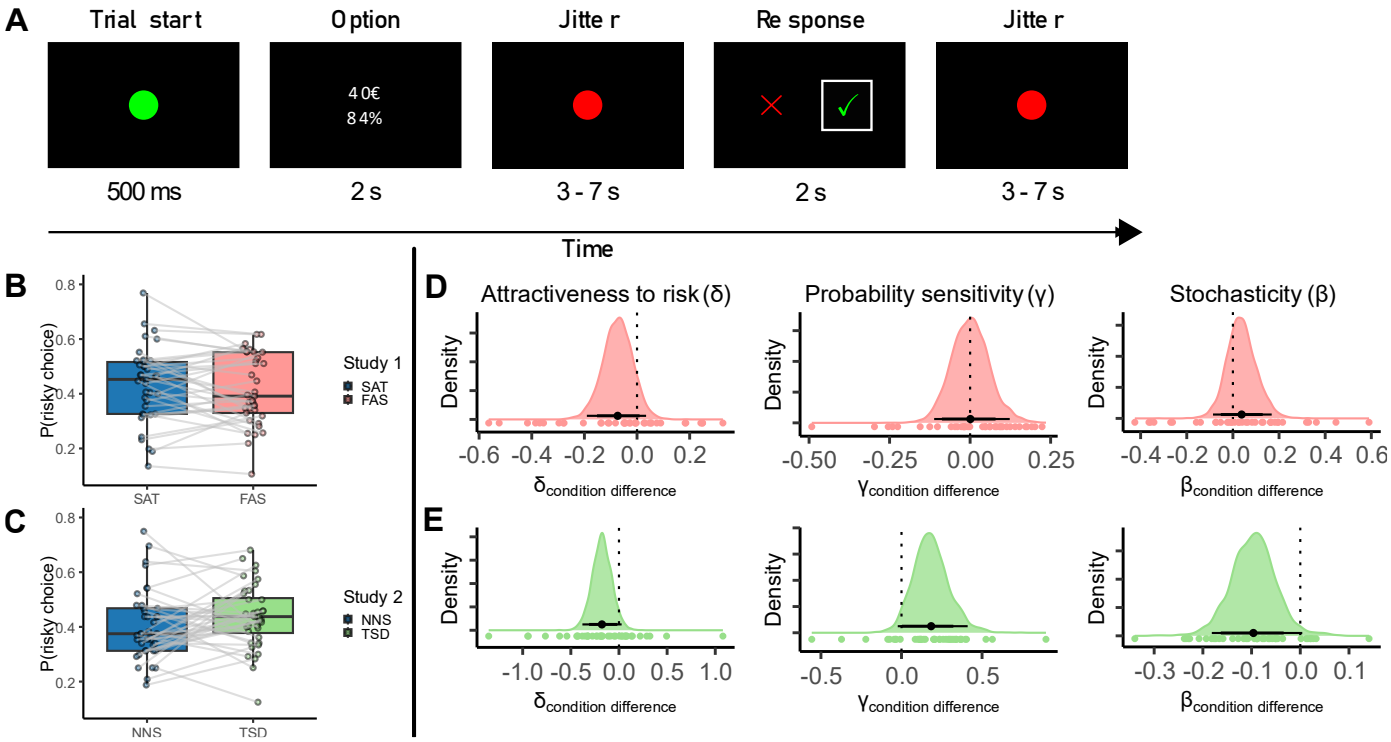

Figure 1: A) An example trial of the probability discounting task $(Ntrials_{Study1} = 96, Ntrials_{Study2} = 48)$. B & C) There was no effect of the experimental condition on the proportion of risky choices in study 1 (B; red) and study 2 (C; green). D & E) There was no difference in the parameter distributions of the PT model between conditions in study 1 (D) and study 2 (E).

Using Bayesian paired t-tests, we found no evidence for a difference in the median proportion of risky choices between conditions in study 1 (Figure 1.B; $BF_{10} = 0.31 \pm 0.04\%$) or study 2 (Figure 1.C: $BF_{10} = 0.52 \pm 0.03\%$).

We compared several cognitive computational models, fitted using hierarchical Bayesian parameter estimation. The best fitting model was the prospect theory (PT) model of Kahneman and Tversky (1979) which calculates the subjective value (SV) of the risky option by weighing the reward probability and has two free parameters (in addition to the stochasticity parameter of the policy, β): the attractiveness of risk (δ) and the sensitivity of probabilities (γ). The estimated parameters did not differ between conditions in either study (Figure 1.D & E). Additionally, we observed no credible evidence for effects of ghrelin on any of the estimated parameters.

To analyse the neural activity related to SV, we used the ROIs ($p < 0.05$, FWE-SVC) from the mask of the Rangel Neuroeconomics laboratory[1]. In both studies were we able to replicate activity in the right PCC and ACC (Bartra et al., 2013; Pearson et al., 2011). We did not find evidence for a modulatory effect of condition or ghrelin levels. This was again true for both studies.

Discussion

In two separate studies, we manipulated ghrelin levels to test the prediction that increases in ghrelin levels would be linked to increased risk taking (Levy et al., 2013; Symmonds et al., 2010; Venkatraman et al., 2007). Neither experimental manipulation (a brief fasting period or one night of total sleep deprivation) induced a change in risky decision-making, both for model-agnostic and computational modelling based measures of behaviour. In addition, we did not observe neural activity related to the experimental manipulation or the increased ghrelin levels. While we are not the first to report the lack of effect (Menz et al., 2012; van Swieten et al., 2023), we are the first to our knowledge that manipulated ghrelin levels in multiple manners.

Our results suggest that the homeostatic influences, in particular from ghrelin, in risky decision-making are weaker than previously thought.

[1] https://www.rnl.caltech.edu/resources/index.html

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