Your decisions are what you eat

Metabolic state can have a serious impact on risk-taking and decision-making in humans and animals

Philip Hunter

The old suspicion that wars are caused by a leader's indigestion does not seem so far-fetched in the light of accumulating evidence that our metabolic state can influence rational decision-making and our approach to risk. For decades, scientists have demonstrated links between the availability and quality of food and behaviour in animals, but it is only recently that these studies have been extended to humans, with potential implications for governments, corporations and individuals in positions of power. The results confound conventional wisdom that has held that metabolic conditions in response to factors such as eating and exercise have no impact on fundamental decision-making processes; rather, these have been held to be driven purely by external factors. "The traditional economic literature and theory regards the internal workings of individuals' brains as a "black box", contributing noise to the decision-making process, but without acknowledging the potential for systematic decision-making biases arising from purely biological factors," commented Mkael Symmonds at the Department of Clinical Neurology at Oxford University in the UK.

However, not all economists and psychologists have been blind to the role of metabolic factors in critical decision-making. Daniel Kahneman, who was a professor of psychology at Princeton University (USA), and won the Nobel Prize for Economics in 2002 for his work on the psychology of judgement and decision-making, gives several examples in his book *Thinking Fast and Slow* [1]. The most famous of these was based on a study of Israeli judges showing that the proportion of requests for parole that were granted peaked just after lunch and then decreased as a function of time during the rest of the

day [2]. Kahneman concluded that hungry or "ego-depleted" judges tend to give less careful consideration to details of the cases, and would more often reach the safe position of denying parole requests. If matters as important as parole requests are influenced by an individual's metabolism, it is not a great stretch to conclude that this might also apply to decisions made by others in positions of power.

Whilst Kahneman's evaluation of judges linked 'real-world' behaviour with a metabolic event—eating lunch—the publication of his book coincided with several other studies that associated changes in decision-making with measurable variables relating to energy reserves and nutrient levels. One of the first publications was co-authored by Symmonds and examined whether alterations in metabolic state would systematically modulate decision-making and financial risk-taking in humans [3]. Participants were given different controlled food regimes to create a variety of metabolic states and were then asked to choose from pairs of financial options, such as bets on an outcome, where one entailed greater risk than the other. The team measured circulating levels of two crucial metabolic hormones, acyl-ghrelin, which signals for nutrient uptake and tends to boost appetite, and leptin, which acts in the opposite direction. The peptide ghrelin is produced by P/D1 cells in the stomach and

by the epsilon endocrine cells in the islets of Langerhans in the pancreas, and is normally converted into the acyl form. Leptin is produced by the same cells in the stomach and is an antagonist of ghrelin; between them, they regulate nutrient uptake from the blood and appetite. The two measures together enabled the team to correlate changes in baseline metabolism in response to a meal with both immediate and delayed effects on risk-taking. They concluded that human risk preferences are "exquisitely sensitive to current metabolic state, in a direction consistent with ecological models of feeding behaviour." Participants became more risk-seeking when hungry and risk-averse when satiated.

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Symmonds' ground-breaking work was followed by a few other studies, such as the work by Dino Levy and colleagues at Tel Aviv University in Israel, again examining how risk-taking varies with metabolic state, but focusing more on the impact of hunger [4]. Levy's study confirmed earlier findings that, on average, people become more risk-tolerant when hungry, and also showed that the extent of the change varied consistently with an individual's baseline attitude to risk. People who were naturally risk-averse became less so when hungry, but participants in the study who were more disposed to risk-taking actually became more risk-averse when hungry, contradicting the general trend. The study also found that changing attitudes to risk in line with metabolism applied equally to all rewards and not just financial ones,

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suggesting that common ancestral neurological structures or mechanisms were involved in each case. This led the authors to conclude that their findings “demonstrate a more complicated interaction between internal state and risk preferences and raise some interesting implications for both day-to-day decisions and financial market structures.”

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These more nuanced findings resonate with studies of animals that investigated the impact of natural changes in the availability of food on risk-seeking behaviour. A Harvard University (USA) study of the feeding and hunting habits of wild chimpanzees found that the animals became more risk-seeking when diet quality and, therefore, nutrient availability was high compared with when it was low [5]. On the basis of 14 years’ worth of data on the Kanyawara chimpanzees of Kibale National Park in Uganda, the authors of the study found that the animals conformed with the long-established ‘scarcity/risk’ hypothesis when food was short, to minimize the risk of starvation, but followed an ‘abundance/risk’ strategy when food was plentiful. According to Ian Gilby and Richard Wrangham, the authors, chimpanzees eat an omnivorous diet with a preference for ripe drupe fruits, such as mangoes, because of their high general nutrient value. However, when the drupes are abundant—they vary seasonally—the chimps actually increase their hunting for meat, primarily the red colobus monkeys, because they can afford to expend more energy: hunting often fails and therefore generates a net loss in energy. But the effort is worth it when the regular diet is readily available, because the meat provides nutrients not found in fruit. Meat is a good source of protein, amino acids and various micronutrients, including iron and selenium, in a bioavailable form.

The discovery of this abundance/risk strategy might provide a clue to why humans who are risk-seeking actually become less so when hungry, although the timescales involved are different. It might be a behaviour inherited from ancestors who stepped up hunting activity when there was plenty

of food around, because they could afford to. But individuals who were generally more risk-averse tended not to get involved in hunting unless they had to and would only do so when hungry, hence conforming with the scarcity/risk hypothesis.

These examples all come under the heading of risk sensitivity theory (RST), which dates back more than 30 years [6]. It holds that animals become more or less risk-seeking depending on their survival needs, such that they might hunt dangerous prey if nothing else is available. RST also embraces the abundance/risk hypothesis, which states that risk-taking is determined by overall nutritional needs. But RST is modified by another factor, known as state-dependent valuation, according to Sarah Heilbronner from the University of Rochester Medical Centre in New York, USA, who has studied risk-seeking behaviour in macaques.

“This second line of research is about how we learn about rewards when we come across them in different metabolic states,” Heilbronner explained. “Have you ever had the experience of going out to a restaurant when you were extremely hungry, then feeling like you had a terrific meal? Maybe you went back to that restaurant when you weren’t as hungry, and it turned out the food was only so-so all along. It turns out this effect, state-dependent valuation, is highly generalizable across species. Even grasshoppers prefer a food item that they first encountered or learned about when they were hungry.” This indicates that an animal’s or human’s attitude to a particular food source can be determined by past history as well as present metabolic state.

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Heilbronner added that there are other apparently subjective factors that affect the individual evaluation of risk in humans. These include fear, which increases risk aversion—applicable to many animals as well—and anger, which causes risk-seeking. These can make evaluations and decisions seem illogical and inconsistent. “In general,

decision-making is subject to tons of biases and oddities that don’t exactly fit what we expect people to do,” Heilbronner said.

A question arising from the work on decision bias is the extent to which it can be mitigated whenever judgement should be based solely on consideration of external factors, as in the case of parole awards. “Some of these factors are hard to control for,” Heilbronner commented. “If somebody’s lunch or morning mood impacts their decision-making, that may be hard to deal with. But others factors are predictable and manageable. For example, we know that people tend to take more risks when decisions are quickly repeated, maybe because they think they can make up for any early losses. Slot machines probably take advantage of this. If we want risk-taking to reduce, we may want to lengthen the required time between decisions.”

However, it is important not to exaggerate the impact of metabolic and other biases in decision-making, according to John Pearson, who studies factors affecting human evaluation and choices at the Centre for Cognitive Neuroscience, Duke University, USA: “One thing that’s worth keeping in mind in all these cases is that many of these effects, while real, are nonetheless small. While the time until lunch, or the colour of the wallpaper, or the tempo of music, or the person I encountered in the hallway on my way to work can all have an effect on me, it’s helpful to keep in mind that despite it all, our decisions do tend to be governed by our larger goals and not the random minutiae of our lives.”

Whilst this might be true of the many small day-to-day decisions most people take, there is still such a thing as systematic bias related to the timing of meals. In some cases, it is possible to observe the impact of meal-timing on decision-making across a group of people when they all have a similar regime. An obvious example is the month of Ramadan, when Muslims fast and avoid drinking during daylight hours. Two studies have highlighted how stock market volatility declines sharply in Muslim countries during Ramadan [7,8]. It seems that hungry people feel less able to afford speculative risks. This has obvious application for speculators, who can exploit the anticipated dampening of stock movements. As Levy and colleagues also note, the observations

about Ramadan imply that decision-making at the population level could be affected even more drastically under deprivations caused by wars, famines or disease outbreaks in ways that policy-makers might want to be aware of at the very least [4].

In the case of war or famine, the impact might be hard to assess, but Symmonds suggests that it might be possible to correct for daily metabolic variation. "One could suggest that having information about how an individual responds neurobiologically to, for example, a calorific load, could help mitigate against decision-making biases, I guess in a similar way to psychometric

profiling, which is routinely used in the business world," he explained.

The other related question is the impact of longer-term changes in metabolic states associated with conditions such as diabetes or obesity on decision-making. This is also of interest to researchers in psychiatry, such as Roger McIntyre, who specializes in mood disorders at the University Health Network, Toronto, Canada. "The major implication of this work on metabolism is that if mental disorders are in some individuals a consequence of a disturbance in bioenergetics, then normalizing abnormal bioenergetic pathways via disparate interventions holds

promise to treat and/or prevent mental illness," said McIntyre. "This opens up a new list of treatment opportunities."

But it is not just metabolic processes related to food and energy that affect decision-making processes. Other factors such as infectious diseases or low daylight also affect metabolism and thereby rational thinking and risk-related behaviour. In some cases, this can be linked to a measurable change in levels of a particular hormone, such as 5-hydroxytryptamine, which is known to affect mood and risk-taking behaviour, according to Pearson.

"Studies on rapid tryptophan depletion (tryptophan being the precursor of 5-hydroxytryptamine) have shown us that dropping 5-hydroxytryptamine levels can have a measurable effect on risk-seeking," he explained. "It all reinforces the notion that we're not just disembodied thinking machines, independent of our bodies."

Given the apparent fallibility of human rationality in response to hunger, daylight or other factors, one of the remedies for human decision bias could be to delegate this task to computers whenever the relevant human expertise necessary to reach conclusions on the basis solely of evidence or information can be captured. Kahneman made this argument in *Thinking Fast and Slow*, suggesting that, "when in doubt, it's better to trust a computer algorithm." He declared that results "unequivocally show that wherever we have sufficient information to build a model, it will perform better than most human experts." Of course, there are cases for which human discretion or emotion can be important—for example, considering

mitigating circumstances in a criminal trial—but even here, an algorithm could process those factors and provide guidance. What is clear, though, is that this research has opened a kind of Pandora's Box that will lead to the identification of more factors that affect human decision-making. "The effects of our internal state are more subtle and more numerous, I suspect, than we realize," Pearson said. If we therefore cannot trust our own judgement, it might be better to delegate at least some decision-making to more rational algorithms, or to ensure that we eat large lunches before making life-changing decisions.

CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

REFERENCES

1. Kahneman D (2011) *Thinking Fast and Slow*. London, UK: Allen Lane
2. Danziger S, Levav J, Avnaim-Pesso L (2011) Extraneous factors in judicial decisions. *Proc Natl Acad Sci USA* **108**: 6889–6892

3. Symmonds M, Emmanuel JJ, Drew ME, Batterham RL, Dolan RJ (2010) Metabolic state alters economic decision making under risk in humans. *PLoS ONE* **5**: e11090
4. Levy DJ, Thavikulwat AC, Glimcher PW (2013) State dependent valuation: the effect of deprivation on risk preferences. *PLoS ONE* **8**: e53978
5. Gilby IC, Wrangham RW (2007) Risk-prone hunting by chimpanzees (*Pan troglodytes schweinfurthii*) increases during periods of high diet quality. *Behav Ecol Sociobiol* **61**: 1771–1779
6. Stephens DW (1981) The logic of risk-sensitive foraging preferences. *Anim Behav* **29**: 626–629
7. Białkowski J, Etebari A, Wisniewski TP (2012) Fast profits: investor sentiment and stock returns during Ramadan. *J Bank Financ* **36**: 835–845
8. Seyyed FJ, Abraham A, Al-Hajji M (2005) Seasonality in stock returns and volatility: the Ramadan effect. *Res Int Bus Financ* **19**: 374–383

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