COMMENTARY

The innovative brain

'Hot' decision-making, involving the evaluation of reward and punishment, is essential to the entrepreneurial process and may be possible to teach, argue Barbara Sahakian and her coauthors.

The creativity and innovation shown by entrepreneurs is a crucial source of employment and economic growth. Although there is potential for considerable profit in making the decision to 'go it alone', rather than working for an existing company, these individuals accept considerable risk. Many new ventures fail, with possible consequences for finances, reputation, self-esteem and even family stability.

Psychological and biomedical research has traditionally considered risk-taking an abnormal expression of behaviour, as exemplified by its association with substance abuse and bipolar mania[1]. We propose that entrepreneurs represent an example of highly adaptive risk-taking behaviour, with positive functional outcomes in the context of stressful economic decision-making. This 'functional impulsivity' may have evolutionary value as a means of seizing opportunities in a rapidly changing environment.

Here, we present preliminary neurocognitive data from matched groups of entrepreneurs and managerial controls, which highlight the potential of this approach to examine advantageous risk-taking. Our 16-member entrepreneurial group from the 'Silicon Fen'[2] cluster of high-tech companies around Cambridge, UK, consists of individuals who have founded at least two companies. Seventeen non-founding managers lacking the experience of venture creation were recruited as a comparison group who were matched to the entrepreneurs for demographic characteristics including age and intelligence, estimated with the National Adult Reading Test.

All the participants completed a computerized neurocognitive assessment that measured various aspects of their decision-making abilities. Classical models of decision-making from psychology and economics focus on the computation of expected values for each decision option, based on the relative gains and losses of the associated outcomes. But these models fail to accommodate emotional states when computing decisions, as well as emotional reactions to gains and losses, which can greatly alter our reasoning processes[3]. A growing body of evidence from functional neuroimaging and studies of patients with brain injuries points to the involvement of distinct processes in risky and risk-free decision-making. Referred to as 'hot' and 'cold' processes, these appear to be localized to distinct regions of the brain's frontal lobes[4].

All in the mind

We measured cold processes using the one-touch Tower of London task (Fig. 1), which requires the participant to mentally rearrange an array of coloured balls. They are required to select the minimum number of moves to complete the problem from a display across the foot of the screen. The problem difficulty varies between one and six moves, with harder problems requiring greater planning, working memory and decision-making skills.

Performance on this task reflects cold processes that are dependent upon the dorsolateral prefrontal cortex[5]. These are emotionally neutral decisions with no weighing of rewards and punishments. Cold processes govern real-life decisions such as planning the details involved in opening of a new company branch.

Risky or hot decisions, on the other hand, involve an evaluation of reward and punishment, with emotional significance attached to both outcomes. For example, the decision between financing one of several potentially excellent but risky business opportunities is a hot decision; it is difficult to ignore emotions. Hot processes are dependent on the medial and orbital sectors of the prefrontal cortex[6], which lie above the orbit of the eyes and connect with limbic emotion-related areas such as the amygdala.

Hot processes were measured using the Cambridge Gamble Task[7] (Fig. 2). A participant is presented with an array of ten boxes coloured either red or blue. A token is hidden randomly in one of the boxes, and the participant must decide whether the token is in a red box, or a blue box. The ratio of red-to-blue boxes is manipulated to present different levels of uncertainty of winning.

Participants then choose a bet to stake on the colour decision. A displayed points total reminds participants how well they are doing. Thus, on each trial, subjects must balance the chance of gaining more points with a high bet against the chance of being incorrect and losing their wager.

Our groups of entrepreneurs and managers showed comparable performance on the Tower of London test of cold processes, with no differences in the number of solutions solved at the first attempt. On the Cambridge Gamble Task, both groups were able to make high-quality decisions, selecting the majority colour at least 95% of the time. The remaining 5% is likely to be accounted for by 'gambler's fallacy' in which subjects try to second guess the computer by choosing the less likely colour. However, when subjects were introduced to the hot components of the task, differences were observed. We found

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that entrepreneurs behaved in a significantly riskier way, betting a greater percentage of their accrued points (63%) than their managerial counterparts (51%). Both groups adjusted their wagering according to the likelihood of success (dependent on the ratio of red-to-blue boxes). The only performance difference was the amount that was bet.

Interestingly, this risk-taking performance in the entrepreneurs was accompanied by elevated scores on personality impulsiveness measures and superior cognitive-flexibility performance. We conclude that entrepreneurs and managers do equally well when asked to perform cold decision-making tasks, but differences emerge in the context of risky or emotional decisions.

The pattern of performance seen on the gambling task in entrepreneurs reflects a behavioural index of risk-seeking or risk tolerance. Greater rewards (as well as greater losses) are available for those who bet more. A large normative study of the Cambridge Gamble Task found that the betting behaviour decreases with age across the lifespan[8]. Comparing our recent data against this normative sample shows that the entrepreneurs (mean age 51) are comparable to the young adults aged 17–27, whereas the managers (mean age 50.5) resemble their age-appropriate group (Fig. 3). These cognitive processes are intimately linked to brain neurochemistry, particularly to the neurotransmitter dopamine. Using single-dose psychostimulants to manipulate dopamine levels, we have seen modulation of risky decision-making on this task[9]. Therefore, it might be possible to enhance entrepreneurship pharmacologically.

The dark side?

Entrepreneurs demonstrate creativity through the development of positive financial opportunities for society as well as themselves. Although we know little about the psychopathological 'dark side' of entrepreneurship[10], we would argue that the effects seen with our gambling task reflect functional impulsivity[11], a subtype of impulsiveness that may enable impulsive individuals to capitalize on environmental niches. This functional impulsiveness of entrepreneurs combined with enhanced cognitive flexibility is a winning combination.

Our results raise important questions: if these impulsive risk-taking traits can be beneficial, can they be taught or otherwise imparted to the potential entrepreneur? What does it take to make an entrepreneur — is it an inherited, inbuilt characteristic, or is it acquired, and if so, can it be acquired by anyone? What specific mechanisms lead to the risk tolerance that we have seen in our study? Are entrepreneurs conscious risk seekers, or do they place less weight on risk in their decision-making?

There are courses that teach the 'know-how' of entrepreneurship and, within this, teach how to mitigate risk through extensive business planning and market research. Yet given this new evidence, courses teaching the opposite — risk-tolerance in both behaviour and personality — may also be desirable. Indeed, this may be easier to teach in young adults, in whom higher risk-taking is likely and age-appropriate. We know that perception of risk is particularly sensitive to framing effects; therefore, training potential entrepreneurs to reframe their decisions may encourage greater entrepreneurial activity.

Similarly, negative perception of risk, such as that involved in starting a new venture, could be mitigated by social/cultural norms. One of the beneficial effects of entrepreneurial clusters in regions such as Silicon Fen may be that the increased networking and contact amongst the entrepreneurs works to create a culture that normalizes a more risk-tolerant type of decision-making. One might argue that business skills can be acquired relatively easily from multiple sources. But if one is to boost entrepreneurial activity, and if risk tolerance and the ability to cope with ambiguity are barriers to achieving a cultural shift in society, then more focus is needed on understanding how risk and emotion are integrated into decision-making. ■

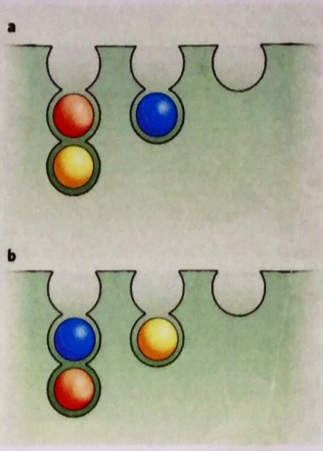

Figure 1 | How many moves? The Tower of London task measures 'cold' decision making, asking subjects to calculate the minimum number of moves required to get the array in **b** to match that in **a**. This is a five-move problem.

Figure 2 | Place your bets. To evaluate risk-taking, 'hot' processes in the Cambridge Gamble Task (part of the Cambridge Neuropsychological Test Automated Battery), a randomly hidden token is in a blue or a red box. Subjects choose a colour and a stake to bet.

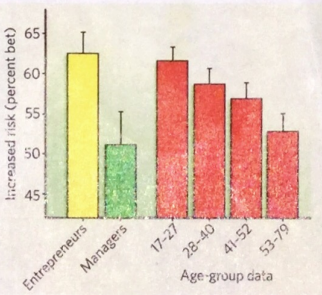

Figure 3 | Risk taking. Entrepreneurs bet a higher percentage of their points than managers. This measure decreases with age in a large normative sample. Managers resemble their age-appropriate counterparts, whereas entrepreneurs show a risk-tolerance similar to the youngest group.

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