PHILOSOPHICAL TRANSACTIONS B

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# Risk taking and impulsive behaviour: fundamental discoveries, theoretical perspectives and clinical implications

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Our willingness to take risks, our ability to wait or the speed with which to make decisions are central features of our personality. However, it is now recognized that impulsive and risk-taking behaviours are not a unitary construct, and different aspects can be both psychologically and neurally dissociated. The range of neurochemicals and brain systems that govern these behaviours is extensive, and this may be a contributing factor to the phenotypic range seen in the human population. However, this variety can also be pathological as extremes in risk-taking and impulsive behaviours are characteristics of many neuropsychiatric and indeed neurodegenerative disorders. This spans obsessive–compulsive disorder, where behaviour becomes ridged and non-spontaneous, to the nonsensical risk-taking seen in gambling and drug taking.

This article is part of the theme issue 'Risk taking and impulsive behaviour: fundamental discoveries, theoretical perspectives and clinical implications'.

## 1. Introduction

> . . .our impulses are too strong for our judgement sometimes
>
> – Thomas Hardy, Tess of the D'Urbervilles

How we respond in the face of a changing social and/or non-social environment is fundamental to human personality, and is an important facet of all animal behaviour. Underpinning this response is our willingness to take risks, our ability to wait or the speed with which we make decisions. At face value, risk-taking behaviour and impulsive behaviour are one and the same. However, research over a number of decades has established not only that risk taking and impulsivity can be dissociated, in terms of delay discounting for example [1,2], but that impulsivity itself is not a unitary construct and that a number of distinct facets are behaviourally dissociable [3–5]. More recent research has demonstrated that these are not simply descriptive distinctions, as we now know that discrete aspects of impulsive behaviour are mediated by different brain circuitries and neurochemistries [6,7], and that variations in these different forms of impulsive behaviour often do not correlate [8]. Moreover, a large range of psychiatric disorders, spanning obsessive–compulsive disorder, where behaviour becomes ridged and non-spontaneous, to the nonsensical risk-taking seen in gambling and drug taking, are classified as having an impulsive component. Yet, these too present with different patterns of impulsive behavioural abnormalities [9–11], leading to distinct therapeutic strategies for different impulse control disorders [12].

Our aim, when compiling this Theme Issue, was to broadly explore impulsive and risk-taking behaviour. Collectively, the papers discuss the distinctions between discrete behaviours, the basic neural mechanisms and clinical conditions

## Introduction

**Cite this article:** Isles AR, Winstanley CA, Humby T. 2019 Risk taking and impulsive behaviour: fundamental discoveries, theoretical perspectives and clinical implications. *Phil. Trans. R. Soc. B* **374**: 20180128.
http://dx.doi.org/10.1098/rstb.2018.0128

Accepted: 3 December 2018

One contribution of 14 to a theme issue 'Risk taking and impulsive behaviour: fundamental discoveries, theoretical perspectives and clinical implications'.

**Subject Areas:**
behaviour, cognition, computational biology, neuroscience, theoretical biology

**Keywords:**
impulsivity, risk, psychiatric illness, evolution, neurobiology

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where abnormal risk-taking or impulsive behaviour is a feature. Additionally, a number of papers also consider the theories relating to how risk-taking and impulsive behaviour is generated within the brain, and how it may have developed over evolutionary time. Nevertheless, one aspect that is not covered specifically, in any great detail, in this Theme Issue is the genetic contribution to impulsive and risk-taking behaviours, despite the fact there are a great many studies linking single genes with aspects of impulsive behaviour and risk-taking. These include numerous rodent studies where the expression of a key candidate gene has been manipulated resulting in changes in impulsive and/or risk-taking behaviours [13–17], and even rare mutations in human families that link single genes to impulsive, risky or violent behaviour [18,19]. However, more general analyses of genetic variation and/or heritability are limited to a handful of rodent experiments [20–23] and twin studies in humans [24]. Moreover, convincing examples of hypothesis-free genome-wide studies of risk-taking and impulsive behaviour are limited. A recent genome-wide association study (GWAS) of delay discounting performance with 23 217 participants identified only one genome-wide significant single-nucleotide polymorphism [25]. Although located in a convincing target associated with the serotonin system (*GPM6B*), this is obviously a disappointing return.

The reason for this is probably because of the issue outlined above, and explored in greater detail by a number of papers in this special issue, which is that impulsivity and risk-taking behaviours represent many distinct constructs that interact in a number of complex ways. This is in contrast to simpler measures, such as height and body-mass index (BMI), in which GWAS studies have produced hundreds of genetic associations [26]. It is probably no surprise that the only really successful genome-wide study thus far has used an operational measure (delay discounting) rather than a broader definition of 'choice impulsivity' [25]. As a consequence, at present it is not possible to provide a cohesive and over-arching analysis of how genetic variation contributes to risk-taking and impulsive behaviours, in the same way that pathway analysis of GWAS data has generated novel insights into the biology of schizophrenia [27,28] and Alzheimer's disease [29] for instance.

## 2. Overview of theme issue

As indicated above, this Theme Issue discusses many aspects of impulsive behaviour and risk-taking, bringing together basic researchers examining the mechanisms underpinning these behaviours, clinicians highlighting how these behaviours differentially impact on a range of conditions, and theorists discussing how brain systems may produce these behaviours and/or how they have developed over evolutionary time. Broadly the papers are grouped in this manner, although, of course, they all touch upon clinical conditions where impulsive or risk-taking behaviour goes awry.

In the first paper, Rosenbaum *et al*. [30] provide an overview of risky and impulsive choice behaviour, with particular emphasis on how these change over the course of development and maturity. The next two papers form a pair, as both examine the conflict between choice of immediate but uncertain food rewards over delayed but certain food rewards. Stokes *et al*. [31] explore how this phenomenon varies in people in relation to BMI, and following exposure to food cues, such as food aroma. These findings have implications for behaviours that contribute to the rise in obesity in environments where food is readily available. Humby *et al*. [32] then describe the development of a touch-screen-based test of this same behaviour in mice. Using a behavioural pharmacology approach, they show that the choice of immediate but uncertain rewards in this task is sensitive to manipulations of $5HT_{2C}R$, a key receptor mediating the effects of serotonin on both impulse control [33–35], and appetite [36,37].

Also addressing the psychology of conflict over choices, Studer *et al*. [38] explore whether precommitment strategies can aid individuals to achieve effort-requiring goals. The authors used two tasks, one where the choice was between a zero effort, small reward option and an increasing effort, large reward option (effort task); and one where the choice was between an immediate small reward option and an increasingly delayed, large reward option (delay task). The precommitment strategy involved choosing to remove the zero-effort or immediate reward option completely, and instead committing to the increasing effort, higher reward option in the effort task or the increasingly delayed, higher reward option in the delay task. In both the effort and delay tasks, where precommitment was chosen in trials, participants improved their rates of obtaining the larger reward. In addition, the authors used computational models of the choice behaviour to demonstrate that participants used precommitment to optimize their choice of the larger (but more effortful- or delayed-) reward by eliminating opportunity costs (i.e. as a self-motivational measure), rather than to prevent anticipated failures (i.e. as a self-regulatory measure). These data have obvious practical implications, and suggest the use of precommitment schemes in exercise and rehabilitation interventions.

Dalley & Ersche [39] dig more deeply into the neurobiology of one aspect of impulsivity, namely waiting impulsivity. Reviewing both animal and human studies, they detail the brain systems and neurotransmitters involved in mediating the ability to withhold a prepotent response until required. In addition to focusing on the fundamental mechanisms, this article links nicely with the next grouping of papers, more focused on clinical aspects. Specifically, Dalley & Ersche argue the importance of waiting impulsivity as a dimensional trait determining the predisposition to disorders of incentive motivation, particularly drug addiction. Moreover, they highlight the role of the serotonin system in the development of compulsive drug taking.

The relationship between impulsivity and drug addiction is explored further by Vassileva & Conrod [40] and Leeman *et al*. [41]. Vassileva focuses on how treatments could be directed at addressing domains of impulsivity as a novel clinical intervention for substance use disorders. Leeman *et al*. extend the role of impulsivity in addiction to include sexual tendencies in the light of the inclusion of compulsive sexual behaviour in the most recent edition of the *International Classification of Diseases*. Their systematic review supports the idea of a role for abnormal impulsivity as a precipitating factor or a consequence of addictive and/or sexual behaviours, but highlights gaps in the literature that need to be addressed with further, focused research.

The next two review articles broaden the discussion of impulsivity and risk-taking in the clinical context to include psychiatric disorders more generally. Lijffijt *et al*. [42] specifically focus on suicidality in bipolar disorder. They argue that the interaction between premorbid impulsivity and behavioural sensitization (in this case, the failure to reduce

arousal in response to salient stimuli) can lead to a progression of psychiatric disorders. Lopez-Guzman *et al*. [43] discuss the interaction between choice impulsivity, as measured by delay discounting, and risk aversion. Although behaviourally and neurally distinct, the authors discuss the mathematical relationship between these two constructs, and in particular how operational measures of choice impulsivity often fail to take account of attitude to risk. They argue that this relationship may change in a complex manner, but nevertheless be key to understanding measures of choice impulsivity across a range of psychiatric disorders.

The remaining articles in this Theme Issue are more theoretical. Hertwig *et al*. [44] maintain that different approaches that have been developed to measure risk preference in behavioural sciences and economics have led to 'gaps' in our understanding of how stable risk preference is. They argue that the self-report measures, used in the behavioural sciences, show a higher degree of convergent validity and temporal stability than the behavioural measures typically used to study economic choice. Although possibly a controversial position, Hertwig *et al*. suggest that future research needs to address these gaps to test their predictive validity for economic and health consequences. Also approaching the topic of risk taking from an economic perspective, Bossaerts *et al*. [45] reason that current theories of decision-making, which model uncertainty about decision options using the tools of probability theory, may not be effective. They argue that in many situations, models, such as the Savage framework, are computationally intractable and, in situations in which computational complexity is high, ineffective in representing uncertainty. The authors conclude that new theories of decision-making, plausible from both a computational perspective and a biological perspective, are required from a scientific perspective and a public policy perspective.

The final two papers place impulsive behaviour and risk-taking in an evolutionary context. Hayden [46] takes a wide-ranging look at the issue of why impulsive and risk-based decisions appear to be sub-optimal (i.e. that choices do not maximize economical potential). Reasoning that the neural origins of self-control are primarily cognitive, Hayden also suggests that a more objective view tells us that although sub-optimal choice is, on the face of it, a flaw, it is universal and is the product (or by-product?) of success over evolutionary time, therefore presumably is optimal in terms of biological function. Wilkins and Bhattacharya provide the theoretical basis for one possible contributing factor to why humans and animals may not appear optimal in their risk-taking and impulsive choices. Here, however, the focus is not on the psychological or behavioural level, but at the level of the gene. Specifically, they argue that the difference in reproductive variance between males and females—in many populations, male reproductive success is limited by access to females, whereas female reproductive success is mainly limited by physiology—can lead to differences in the 'willingness' of genes to be exposed to risk in the next generation. In particular, this has connotations for imprinted genes, a sub-set of mammalian genes that are differentially marked in a parent-of-origin-specific manner leading to monoallelic expression from one parental copy of the gene only. In the population scenario described above, the suggestion is that paternally expressed imprinted genes would broadly act to *reduce* risk-taking, whereas maternally expressed imprinted genes would be more tolerant of risk-taking due to their exposure to different rates of the reproductive variance in the previous generation. Indeed, recent work examining knockout mouse models of two imprinted genes, *Nesp* and *Grb10*, provides broad empirical support for this idea [13,14]. It is easy to see how such a genetic tug-of-war may produce impulsive or risk-taking behaviour that appears sub-optimal.

## 3. Conclusion

Our aim is that the wide-ranging articles in this issue place our current understanding of risk-taking and impulsive behaviours in context. Nevertheless, what is abundantly clear is that there is still much work to be done in this field, at all levels of understanding. However, in bringing together a collection of papers that touch upon the basic and clinical science, and theoretical ideas, we hope this special issue will stimulate more research, but particularly cross-discipline research, into risk-taking and impulsive behaviours.

Data accessibility. This article has no additional data.

Competing interests. The authors declare they have no competing interests.

Funding. A.R.I. and T.H. are part of the MRC Centre for Neuropsychiatric Genetics and Genomics (G0801418).

Acknowledgements. We thank Helen Eaton, Commission Editor of the journal, for her continuous support, help and patience during our time as guest editors for this Theme Issue. We would also like to thank all the authors who have contributed, and all the referees for their conscientious work.

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