Play it again, John

A look back at the birth of game theory some 60 years ago.

Theory of Games and Economic Behavior: Sixtieth-Anniversary Edition

by John von Neumann & Oskar Morgenstern
Princeton University Press: 2004. 704 pp.
\$50, £32.50

Karl Sigmund

"Posterity may regard this book as one of the major scientific achievements of the first half of the twentieth century." So began a 1945 review of this book in the *Bulletin of the American Mathematical Society*. There followed a rash of equally enthusiastic articles, including one on the front page of the Sunday issue of *The New York Times* — enough to make any publisher walk on air. This sixtieth-anniversary edition of *Theory of Games and Economic Behavior* is a fitting sign of lasting gratitude from Princeton University Press.

As well as being an achievement in the first half of the twentieth century, the book proved a pacemaker for its second half. A 600-page monograph usually represents the summing-up of a mature scientific field. In this case it was the birth cry of game theory. The theory is no great help for playing poker, but uses terms such as 'player', 'move' and 'pay-off' to analyse social interactions.

The field developed in ways that were hardly anticipated by the book's authors, John von Neumann and Oskar Morgenstern. In 1950, a 20-year-old called John Nash introduced a fundamental equilibrium concept, daring, as he later said, "to deviate from the line (in the sense of party line)" laid down by the two founders of the field. But the economic establishment remained aloof for some time. At first, the field grew mostly through the work of brilliant young mathematicians with only a minimal background in economics, and ideas that were very much their own. One of them, Harold Kuhn, has written the introduction to this reissued edition.

One of the main parts of the book, the theory of two-person zero-sum games, analyses situations of pure competition, which later were felt to be of only marginal relevance to most economic interactions. But this theory, which was mathematically equivalent to linear programming, became one of the hottest topics of the 1950s, leading to several Nobel Prizes in economics. Another main section of the book is devoted to a theory of coalitions, centred on a solution concept that, as it later turned out, could not always be fulfilled. Von Neumann and Morgenstern had stated that "such an

Game for anything: it's hard to guess what people will do, as human behaviour is often irrational.

eventuality would certainly necessitate a fundamental change in the theory".

Moreover, von Neumann and Morgenstern had intended a "General theory of rational behavior" (the original book title, fortunately dropped), prescribing what rational agents ought to do. It was based on an axiomatic treatment of personal utility that was plausible but was later shown to be in patent contradiction to actual human behaviour. As Ariel Rubinstein writes in an afterword to this anniversary edition, game theory does not have normative implications. Rather, it is a cousin of logic, a mathematical tool more useful for description than for prediction. Today, game theory is used routinely in evolutionary biology, helping to analyse societies of animals or bacteria. In the same vein, experimental economics based on simple games has grown tremendously, but without finding much rationality.

The value of the book is largely historical today, having been superseded in most classrooms by Duncan Luce and Howard Raiffa's *Games and Decisions*, which appeared in 1957. But this history is exciting. What did von Neumann and Morgenstern have in common, apart from an Austro-Hungarian background and a neighbourhood in Princeton? 'Good-time Johnny', as von

Neumann was known, a Wunderkind come to joyful maturity, was universally hailed as a mathematical genius of amazing versatility. He wrote ground-breaking papers on formal logic, quantum theory, functional analysis and group representations. Morgenstern, a maverick economist, struggled all his life with elementary mathematics but never gave up.

It is said that von Neumann was both the father and the mother of the book, and Morgenstern its midwife. During the 1940s, von Neumann launched into a stupendous variety of mathematical contributions to ballistics, sea mines, thermonuclear explosions and programmable computers. The general view is that, in between his restless travels, he occasionally breezed into Princeton with a handful of notes on game theory, explained them (in German) to Morgenstern, far into the night, and left him with the task of typing it all up. But Morgenstern's article describing the collaboration, and particularly his diaries — kept at Duke University in Durham, North Carolina, and analysed by historian of economics Robert Leonard — suggest that the meeting of minds went deeper than that.

In 1928, von Neumann had published in Berlin a paper on parlour games. Meanwhile Morgenstern, in Vienna, published a book entitled *Wirtschaftsprognose*, in which he

claimed that economic predictions are in principle inconsistent, because they cause agents to act in a different way from that predicted. His favourite example was the fictional detective Sherlock Holmes being pursued by the murderous Moriarty and having to decide where to leave a train, with Moriarty anticipating this, in a vicious circle of mutual outguessing. Morgenstern, the director of a forecasting agency in Austria, saw in this infinite regress ("He thinks that I think that he thinks...") a basic obstacle to forecasting the decisions of interacting individuals, no less fundamental than the uncertainty principle or the incompleteness theorem. Only later did he realize that von Neumann's 'maximin' solution, yielding the highest guaranteed payoff, offered a way out: mixed strategies (such as 'leave at Dover with probability of two-thirds') can be optimal, even if an adversary manages to guess them.

Although Morgenstern's love affair with mathematics was purely one-sided, he was closely acquainted with some of Vienna's best mathematicians, including the geometer Karl Menger, who co-discovered dimension theory, and the logician Kurt Gödel. Menger was so distressed by the political turmoil of the time that in autumn 1934 he withdrew to a mountain resort, where he wrote an odd little booklet on mathematical ethics, based on the 'tolerance principle'. Just as there is not one geometry but many (euclidean, hyperbolic and elliptic, for example), so there is not one system of moral norms but many, from which individuals make their own choice. Menger then studied how groups of adherents to different norms interrelated.

In 1938, Morgenstern was prevented from returning to Austria from the United States by the Nazis, who had blacklisted him. During his exile in Princeton, he sought to extend Menger's ideas in a paper on "Maxims of behavior", and to analyse societies of agents whose decisions impinge on each other. This was when von Neumann, who had not worked on game theory for ten years, stepped in, and eventually suggested that they write the paper together, for the benefit of economists. "Here was my gift from heaven," wrote Morgenstern. Their manuscript started growing relentlessly, becoming first a two-part paper, then a small pamphlet that Princeton University Press agreed to publish, and then the authors "completely forgot about any restriction to 100 pages".

The final product is not for the faint-hearted, and few will have had the stamina to work through its pages crammed with footnotes and formulae. But by its mere existence, the heavy tome marked a turning point in economics, challenging it to become a mathematical discipline at last. ■

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Into the depths: the body can muster an extraordinary range of defences against extreme conditions.

Life on the edge

The Biology of Human Survival: Life and Death in Extreme Environments

by Claude A. Piantadosi
Oxford University Press: 2003. 280 pp.
£24.95, \$35

Mike Stroud

Stories of human achievements and survival against the odds have always been fascinating. Whether in the context of simply living in the world's harshest environments, mounting expeditions to its hottest, coldest, highest or deepest places, or coping with the aftermath of disaster, everybody wonders at just how the body copes. Answers lie in the study of environmental physiology, the responses and adaptations that can take men and women to extremes.

The Biology of Human Survival is an extraordinary environmental physiology text. The topics covered range far beyond biology to include the physics and function of artificial aids that allow humans to cope with extremely hostile environments. But engineering approaches are not just used to describe life-supporting technologies — the author also uses them to explain biological concepts. This approach helped me to understand some concepts that I had previously struggled with. Occasionally, however, the opposite applies.

The book begins by describing the limits to the range of environments that can support human life, along with the principles of survival, adaptation and life-support

systems. The historical background to environmental physiology is fascinating, but as the book moves on to adaptation (physiological changes in response to environmental stress) and maladaptation (adverse changes resulting from adaptation), some topics were unclear and others were made unnecessarily complex. For example, the author stresses the importance of discriminating between technical definitions, such as adaptation, acclimatization, acclimation, accommodation and habituation, but then, I feel, blurs the boundaries. He has also focused particularly on maladaptation and cross-acclimation (adaptive changes to one type of environmental stress that prove beneficial during exposure to stress from a different type of environment), perhaps ascribing more importance to these processes than they deserve. Indeed, he suggests that adverse effects of cross-acclimation between cold and hypoxic responses contribute to the difficulty of climbing Mount Everest in winter. In reality, this must be insignificant compared to winter's cold, storms and jet-stream winds.

But back to the book's strengths. Several chapters cover adaptation to heat and cold in detail. There are lengthy descriptions of human responses and adaptation to icy environments, but our physiological responses to heat (which are far more effective than those to cold) are not covered in such depth. This book is not, then, a definitive work on environmental physiology. But viewed as a collection of thought-provoking pieces about this field it becomes a tour de force. This is especially true when the author strays from his title, covering not just engineering and biology, but also life that is far from