

Game theory

Game theory is the study of mathematical models of strategic interaction among rational decision-makers.^[1] It has applications in all fields of social science, as well as in logic, systems science, and computer science. Originally, it addressed zero-sum games, in which each participant's gains or losses are exactly balanced by those of the other participants. Today, game theory applies to a wide range of behavioral relations, and is now an umbrella term for the science of logical decision making in humans, animals, and computers.

Modern game theory began with the idea of mixed-strategy equilibria in two-person zero-sum games and its proof by John von Neumann. Von Neumann's original proof used the Brouwer fixed-point theorem on continuous mappings into compact convex sets, which became a standard method in game theory and mathematical economics. His paper was followed by the 1944 book *Theory of Games and Economic Behavior*, co-written with Oskar Morgenstern, which considered cooperative games of several players. The second edition of this book provided an axiomatic theory of expected utility, which allowed mathematical statisticians and economists to treat decision-making under uncertainty.

Game theory was developed extensively in the 1950s by many scholars. It was explicitly applied to biology in the 1970s, although similar developments go back at least as far as the 1930s. Game theory has been widely recognized as an important tool in many fields. As of 2014, with the Nobel Memorial Prize in Economic Sciences going to game theorist Jean Tirole, eleven game theorists have won the economics Nobel Prize. John Maynard Smith was awarded the Crafoord Prize for his application of game theory to biology.

Contents

History

- Prize-winning achievements

Game types

- Cooperative / non-cooperative
- Symmetric / asymmetric
- Zero-sum / non-zero-sum
- Simultaneous / sequential
- Perfect information and imperfect information
- Combinatorial games
- Infinitely long games
- Discrete and continuous games
- Differential games
- Evolutionary game theory
- Stochastic outcomes (and relation to other fields)
- Metagames
- Pooling games
- Mean field game theory

Representation of games
Extensive form
Normal form
Characteristic function form
General and applied uses
Description and modeling
Prescriptive or normative analysis
Economics and business
Political science
Biology
Computer science and logic
Philosophy

In popular culture

See also

Notes

References and further reading

Textbooks and general references
Historically important texts
Other print references

External links

Further reading

History

Discussions of two-person games began long before the rise of modern, mathematical game theory. The first known discussion of game theory occurred in a letter believed to be written in 1713 by Charles Waldegrave, an active [Jacobite](#) and uncle to [James Waldegrave](#), a British diplomat.^[2] The true identity of the original correspondent is somewhat elusive given the limited details and evidence available and the subjective nature of its interpretation. One theory postulates Francis Waldegrave as the true correspondent, but this has yet to be proven.^[3] In this letter, Waldegrave provides a [minimax mixed strategy](#) solution to a two-person version of the card game [le Her](#), and the problem is now known as [Waldegrave problem](#). In his 1838 *Recherches sur les principes mathématiques de la théorie des richesses* (*Researches into the Mathematical Principles of the Theory of Wealth*), [Antoine Augustin Cournot](#) considered a [duopoly](#) and presents a solution that is the [Nash equilibrium](#) of the game.

In 1913, [Ernst Zermelo](#) published *Über eine Anwendung der Mengenlehre auf die Theorie des Schachspiels* (*On an Application of Set Theory to the Theory of the Game of Chess*), which proved that the optimal chess strategy is [strictly determined](#). This paved the way for more general theorems.^[4]

In 1938, the Danish mathematical economist [Frederik Zeuthen](#) proved that the mathematical model had a winning strategy by using [Brouwer's fixed point theorem](#).^[5] In his 1938 book *Applications aux Jeux de Hasard* and earlier notes, [Émile Borel](#) proved a minimax theorem for two-person zero-sum matrix games only when the pay-off matrix was symmetric and provides a solution to a non-trivial infinite game (known in English as [Blotto game](#)). Borel conjectured the non-existence of mixed-strategy equilibria in finite two-person zero-sum games, a conjecture that was proved false by von Neumann.

Game theory did not really exist as a unique field until John von Neumann published the paper *On the Theory of Games of Strategy* in 1928.^[6] Von Neumann's original proof used Brouwer's fixed-point theorem on continuous mappings into compact convex sets, which became a standard method in game theory and mathematical economics. His paper was followed by his 1944 book *Theory of Games and Economic Behavior* co-authored with Oskar Morgenstern.^[7] The second edition of this book provided an axiomatic theory of utility, which reincarnated Daniel Bernoulli's old theory of utility (of money) as an independent discipline. Von Neumann's work in game theory culminated in this 1944 book. This foundational work contains the method for finding mutually consistent solutions for two-person zero-sum games. Subsequent work focused primarily on cooperative game theory, which analyzes optimal strategies for groups of individuals, presuming that they can enforce agreements between them about proper strategies.^[8]

In 1950, the first mathematical discussion of the prisoner's dilemma appeared, and an experiment was undertaken by notable mathematicians Merrill M. Flood and Melvin Dresher, as part of the RAND Corporation's investigations into game theory. RAND pursued the studies because of possible applications to global nuclear strategy.^[9] Around this same time, John Nash developed a criterion for mutual consistency of players' strategies known as the Nash equilibrium, applicable to a wider variety of games than the criterion proposed by von Neumann and Morgenstern. Nash proved that every finite n-player, non-zero-sum (not just 2-player zero-sum) non-cooperative game has what is now known as a Nash equilibrium in mixed strategies.

Game theory experienced a flurry of activity in the 1950s, during which the concepts of the core, the extensive form game, fictitious play, repeated games, and the Shapley value were developed. The 1950s also saw the first applications of game theory to philosophy and political science.

In 1979 Robert Axelrod tried setting up computer programs as players and found that in tournaments between them the winner was often a simple "tit-for-tat" program that cooperates on the first step, then, on subsequent steps, does whatever its opponent did on the previous step. The same winner was also often obtained by natural selection; a fact widely taken to explain cooperation phenomena in evolutionary biology and the social sciences.^[10]

Prize-winning achievements

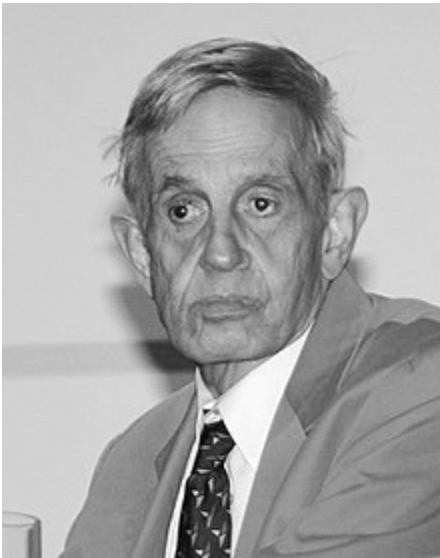
In 1965, Reinhard Selten introduced his solution concept of subgame perfect equilibria, which further refined the Nash equilibrium. Later he would introduce trembling hand perfection as well). In 1994 Nash, Selten and Harsanyi became Economics Nobel Laureates for their contributions to economic game theory.

In the 1970s, game theory was extensively applied in biology, largely as a result of the work of John Maynard Smith and his evolutionarily stable strategy. In addition, the concepts of correlated equilibrium, trembling hand perfection, and common knowledge^[11] were introduced and analyzed.

In 2005, game theorists Thomas Schelling and Robert Aumann followed Nash, Selten, and Harsanyi as Nobel Laureates. Schelling worked on dynamic models, early examples of evolutionary game theory. Aumann contributed more to the equilibrium school, introducing equilibrium coarsening and correlated equilibria, and developing an extensive formal analysis of the assumption of common knowledge and of its consequences.



John von Neumann



John Nash

In 2007, Leonid Hurwicz, Eric Maskin, and Roger Myerson were awarded the Nobel Prize in Economics "for having laid the foundations of mechanism design theory". Myerson's contributions include the notion of proper equilibrium, and an important graduate text: *Game Theory, Analysis of Conflict*.^[1] Hurwicz introduced and formalized the concept of incentive compatibility.

In 2012, Alvin E. Roth and Lloyd S. Shapley were awarded the Nobel Prize in Economics "for the theory of stable allocations and the practice of market design". In 2014, the Nobel went to game theorist Jean Tirole.

Game types

Cooperative / non-cooperative

A game is *cooperative* if the players are able to form binding commitments externally enforced (e.g. through contract law). A game is *non-cooperative* if players cannot form alliances or if all agreements need to be self-enforcing (e.g. through credible threats).^[1]

Cooperative games are often analyzed through the framework of *cooperative game theory*, which focuses on predicting which coalitions will form, the joint actions that groups take, and the resulting collective payoffs. It is opposed to the traditional *non-cooperative game theory* which focuses on predicting individual players' actions and payoffs and analyzing Nash equilibria.^{[2][3]}

Cooperative game theory provides a high-level approach as it describes only the structure, strategies, and payoffs of coalitions, whereas non-cooperative game theory also looks at how bargaining procedures will affect the distribution of payoffs within each coalition. As non-cooperative game theory is more general, cooperative games can be analyzed through the approach of non-cooperative game theory (the converse does not hold) provided that sufficient assumptions are made to encompass all the possible strategies available to players due to the possibility of external enforcement of cooperation. While it would thus be optimal to have all games expressed under a non-cooperative framework, in many instances insufficient information is available to accurately model the formal procedures available during the strategic bargaining process, or the resulting model would be too complex to offer a practical tool in the real world. In such cases, cooperative game theory provides a simplified approach that allows analysis of the game at large without having to make any assumption about bargaining powers.

Symmetric / asymmetric

A symmetric game is a game where the payoffs for playing a particular strategy depend only on the other strategies employed, not on who is playing them. That is, if the identities of the players can be changed without changing the payoff to the strategies, then a game is symmetric. Many of the commonly studied 2×2 games are symmetric. The standard representations of chicken, the prisoner's dilemma, and the stag hunt are all symmetric games. Some scholars would consider certain asymmetric games as examples of these games as well. However, the most common payoffs for each of these games are symmetric.

	E	F
E	1, 2	0, 0
F	0, 0	1, 2

An asymmetric game

Most commonly studied asymmetric games are games where there are not identical strategy sets for both players. For instance, the ultimatum game and similarly the dictator game have different strategies for each player. It is possible, however, for a game to have identical strategies for both players, yet be asymmetric. For example, the game pictured to the right is asymmetric despite having identical strategy sets for both players.

Zero-sum / non-zero-sum

Zero-sum games are a special case of constant-sum games in which choices by players can neither increase nor decrease the available resources. In zero-sum games, the total benefit to all players in the game, for every combination of strategies, always adds to zero (more informally, a player benefits only at the equal expense of others).^[12] Poker exemplifies a zero-sum game (ignoring the possibility of the house's cut), because one wins exactly the amount one's opponents lose. Other zero-sum games include matching pennies and most classical board games including Go and chess.

Many games studied by game theorists (including the famed prisoner's dilemma) are non-zero-sum games, because the outcome has net results greater or less than zero. Informally, in non-zero-sum games, a gain by one player does not necessarily correspond with a loss by another.

Constant-sum games correspond to activities like theft and gambling, but not to the fundamental economic situation in which there are potential gains from trade. It is possible to transform any game into a (possibly asymmetric) zero-sum game by adding a dummy player (often called "the board") whose losses compensate the players' net winnings.

Simultaneous / sequential

Simultaneous games are games where both players move simultaneously, or if they do not move simultaneously, the later players are unaware of the earlier players' actions (making them *effectively* simultaneous). Sequential games (or dynamic games) are games where later players have some knowledge about earlier actions. This need not be perfect information about every action of earlier players; it might be very little knowledge. For instance, a player may know that an earlier player did not perform one particular action, while s/he does not know which of the other available actions the first player actually performed.

The difference between simultaneous and sequential games is captured in the different representations discussed above. Often, normal form is used to represent simultaneous games, while extensive form is used to represent sequential ones. The transformation of extensive to normal form is one way, meaning that multiple extensive form games correspond to the same normal form. Consequently, notions of equilibrium for simultaneous games are insufficient for reasoning about sequential games; see subgame perfection.

In short, the differences between sequential and simultaneous games are as follows:

	Sequential	Simultaneous
Normally denoted by	<u>Decision trees</u>	<u>Payoff matrices</u>
Prior knowledge of opponent's move?	Yes	No
Time axis?	Yes	No
Also known as	<u>Extensive-form game</u> Extensive game	<u>Strategy game</u> Strategic game

Perfect information and imperfect information

An important subset of sequential games consists of games of perfect information. A game is one of perfect information if all players know the moves previously made by all other players. Most games studied in game theory are imperfect-information games. Examples of perfect-information games include tic-tac-toe, checkers, infinite chess, and Go.^{[13][14][15][16]}

	A	B
A	−1, 1	3, −3
B	0, 0	−2, 2

A zero-sum game

Many card games are games of imperfect information, such as poker and bridge.^[17] Perfect information is often confused with complete information, which is a similar concept. Complete information requires that every player know the strategies and payoffs available to the other players but not necessarily the actions taken. Games of incomplete information can be reduced, however, to games of imperfect information by introducing "moves by nature".^[18]

Combinatorial games

Games in which the difficulty of finding an optimal strategy stems from the multiplicity of possible moves are called combinatorial games. Examples include chess and go. Games that involve imperfect information may also have a strong combinatorial character, for instance backgammon. There is no unified theory addressing combinatorial elements in games. There are, however, mathematical tools that can solve particular problems and answer general questions.^[19]

Games of perfect information have been studied in combinatorial game theory, which has developed novel representations, e.g. surreal numbers, as well as combinatorial and algebraic (and sometimes non-constructive) proof methods to solve games of certain types, including "loopy" games that may result in infinitely long sequences of moves. These methods address games with higher combinatorial complexity than those usually considered in traditional (or "economic") game theory.^{[20][21]} A typical game that has been solved this way is hex. A related field of study, drawing from computational complexity theory, is game complexity, which is concerned with estimating the computational difficulty of finding optimal strategies.^[22]

Research in artificial intelligence has addressed both perfect and imperfect information games that have very complex combinatorial structures (like chess, go, or backgammon) for which no provable optimal strategies have been found. The practical solutions involve computational heuristics, like alpha–beta pruning or use of artificial neural networks trained by reinforcement learning, which make games more tractable in computing practice.^{[19][23]}

Infinitely long games

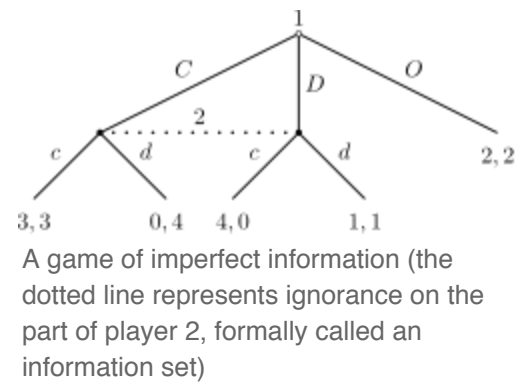
Games, as studied by economists and real-world game players, are generally finished in finitely many moves. Pure mathematicians are not so constrained, and set theorists in particular study games that last for infinitely many moves, with the winner (or other payoff) not known until *after* all those moves are completed.

The focus of attention is usually not so much on the best way to play such a game, but whether one player has a winning strategy. (It can be proven, using the axiom of choice, that there are games – even with perfect information and where the only outcomes are "win" or "lose" – for which *neither* player has a winning strategy.) The existence of such strategies, for cleverly designed games, has important consequences in descriptive set theory.

Discrete and continuous games

Much of game theory is concerned with finite, discrete games that have a finite number of players, moves, events, outcomes, etc. Many concepts can be extended, however. Continuous games allow players to choose a strategy from a continuous strategy set. For instance, Cournot competition is typically modeled with players' strategies being any non-negative quantities, including fractional quantities.

Differential games



Differential games such as the continuous pursuit and evasion game are continuous games where the evolution of the players' state variables is governed by differential equations. The problem of finding an optimal strategy in a differential game is closely related to the optimal control theory. In particular, there are two types of strategies: the open-loop strategies are found using the Pontryagin maximum principle while the closed-loop strategies are found using Bellman's Dynamic Programming method.

A particular case of differential games are the games with a random time horizon.^[24] In such games, the terminal time is a random variable with a given probability distribution function. Therefore, the players maximize the mathematical expectation of the cost function. It was shown that the modified optimization problem can be reformulated as a discounted differential game over an infinite time interval.

Evolutionary game theory

Evolutionary game theory studies players who adjust their strategies over time according to rules that are not necessarily rational or farsighted.^[25] In general, the evolution of strategies over time according to such rules is modeled as a Markov chain with a state variable such as the current strategy profile or how the game has been played in the recent past. Such rules may feature imitation, optimization, or survival of the fittest.

In biology, such models can represent (biological) evolution, in which offspring adopt their parents' strategies and parents who play more successful strategies (i.e. corresponding to higher payoffs) have a greater number of offspring. In the social sciences, such models typically represent strategic adjustment by players who play a game many times within their lifetime and, consciously or unconsciously, occasionally adjust their strategies.^[26]

Stochastic outcomes (and relation to other fields)

Individual decision problems with stochastic outcomes are sometimes considered "one-player games". These situations are not considered game theoretical by some authors. They may be modeled using similar tools within the related disciplines of decision theory, operations research, and areas of artificial intelligence, particularly AI planning (with uncertainty) and multi-agent system. Although these fields may have different motivators, the mathematics involved are substantially the same, e.g. using Markov decision processes (MDP).

Stochastic outcomes can also be modeled in terms of game theory by adding a randomly acting player who makes "chance moves" ("moves by nature").^[27] This player is not typically considered a third player in what is otherwise a two-player game, but merely serves to provide a roll of the dice where required by the game.

For some problems, different approaches to modeling stochastic outcomes may lead to different solutions. For example, the difference in approach between MDPs and the minimax solution is that the latter considers the worst-case over a set of adversarial moves, rather than reasoning in expectation about these moves given a fixed probability distribution. The minimax approach may be advantageous where stochastic models of uncertainty are not available, but may also be overestimating extremely unlikely (but costly) events, dramatically swaying the strategy in such scenarios if it is assumed that an adversary can force such an event to happen.^[28] (See Black swan theory for more discussion on this kind of modeling issue, particularly as it relates to predicting and limiting losses in investment banking.)

General models that include all elements of stochastic outcomes, adversaries, and partial or noisy observability (of moves by other players) have also been studied. The "gold standard" is considered to be partially observable stochastic game (POSG), but few realistic problems are computationally feasible in POSG representation.^[28]

Metagames

These are games the play of which is the development of the rules for another game, the target or subject game. Metagames seek to maximize the utility value of the rule set developed. The theory of metagames is related to mechanism design theory.

The term metagame analysis is also used to refer to a practical approach developed by Nigel Howard.^[29] whereby a situation is framed as a strategic game in which stakeholders try to realize their objectives by means of the options available to them. Subsequent developments have led to the formulation of confrontation analysis.

Pooling games

These are games prevailing over all forms of society. Pooling games are repeated plays with changing payoff table in general over an experienced path, and their equilibrium strategies usually take a form of evolutionary social convention and economic convention. Pooling game theory emerges to formally recognize the interaction between optimal choice in one play and the emergence of forthcoming payoff table update path, identify the invariance existence and robustness, and predict variance over time. The theory is based upon topological transformation classification of payoff table update over time to predict variance and invariance, and is also within the jurisdiction of the computational law of reachable optimality for ordered system.^[30]

Mean field game theory

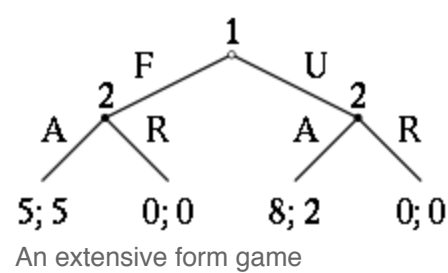
Mean field game theory is the study of strategic decision making in very large populations of small interacting agents. This class of problems was considered in the economics literature by Boyan Jovanovic and Robert W. Rosenthal, in the engineering literature by Peter E. Caines, and by mathematician Pierre-Louis Lions and Jean-Michel Lasry.

Representation of games

The games studied in game theory are well-defined mathematical objects. To be fully defined, a game must specify the following elements: the *players of the game*, the *information* and *actions* available to each player at each decision point, and the *payoffs* for each outcome. (Eric Rasmusen refers to these four "essential elements" by the acronym "PAPI").^[31] A game theorist typically uses these elements, along with a solution concept of their choosing, to deduce a set of equilibrium strategies for each player such that, when these strategies are employed, no player can profit by unilaterally deviating from their strategy. These equilibrium strategies determine an equilibrium to the game—a stable state in which either one outcome occurs or a set of outcomes occur with known probability.

Most cooperative games are presented in the characteristic function form, while the extensive and the normal forms are used to define noncooperative games.

Extensive form



The extensive form can be used to formalize games with a time sequencing of moves. Games here are played on trees (as pictured here). Here each vertex (or node) represents a point of choice for a player. The player is specified by a number listed by the vertex. The lines out of the vertex represent a possible action for that player. The payoffs are specified at the bottom of the tree. The extensive form can be viewed as a multi-player generalization of a decision tree.^[32] To solve any extensive form game, backward induction must be used. It involves working backward up the game tree to determine what a rational player would do at the last vertex of the tree, what the player with the previous move would do given that the player with the last move is rational, and so on until the first vertex of the tree is reached.^[33]

The game pictured consists of two players. The way this particular game is structured (i.e., with sequential decision making and perfect information), *Player 1* "moves" first by choosing either *F* or *U* (Fair or Unfair). Next in the sequence, *Player 2*, who has now seen *Player 1*'s move, chooses to play either *A* or *R*. Once *Player 2* has made his/ her choice, the game is considered finished and each player gets their respective payoff. Suppose that *Player 1* chooses *U* and then *Player 2* chooses *A*: *Player 1* then gets a payoff of "eight" (which in real-world terms can be interpreted in many ways, the simplest of which is in terms of money but could mean things such as eight days of vacation or eight countries conquered or even eight more opportunities to play the same game against other players) and *Player 2* gets a payoff of "two".

The extensive form can also capture simultaneous-move games and games with imperfect information. To represent it, either a dotted line connects different vertices to represent them as being part of the same information set (i.e. the players do not know at which point they are), or a closed line is drawn around them. (See example in the [imperfect information section](#).)

Normal form

The normal (or strategic form) game is usually represented by a matrix which shows the players, strategies, and payoffs (see the example to the right). More generally it can be represented by any function that associates a payoff for each player with every possible combination of actions. In the accompanying example there are two players; one chooses the row and the other chooses the column. Each player has two strategies, which are specified by the number of rows and the number of columns. The payoffs are provided in the interior. The first number is the payoff received by the row player (Player 1 in our example); the second is the payoff for the column player (Player 2 in our example). Suppose that Player 1 plays *Up* and that Player 2 plays *Left*. Then Player 1 gets a payoff of 4, and Player 2 gets 3.

When a game is presented in normal form, it is presumed that each player acts simultaneously or, at least, without knowing the actions of the other. If players have some information about the choices of other players, the game is usually presented in extensive form.

Every extensive-form game has an equivalent normal-form game, however the transformation to normal form may result in an exponential blowup in the size of the representation, making it computationally impractical.^[34]

Characteristic function form

In games that possess removable utility, separate rewards are not given; rather, the characteristic function decides the payoff of each unity. The idea is that the unity that is 'empty', so to speak, does not receive a reward at all.

The origin of this form is to be found in John von Neumann and Oskar Morgenstern's book; when looking at these instances, they guessed that when a union **C** appears, it works against the fraction $\left(\frac{\mathbf{N}}{\mathbf{C}}\right)$ as if two individuals were playing a normal game. The balanced payoff of C is a basic function. Although there are differing examples that help determine coalitional amounts from normal games, not all appear that in their function form can be derived from such.

Formally, a characteristic function is seen as: (N,v), where N represents the group of people and $v : 2^N \rightarrow \mathbf{R}$ is a normal utility.

Such characteristic functions have expanded to describe games where there is no removable utility.

	Player 2 chooses <i>Left</i>	Player 2 chooses <i>Right</i>
Player 1 chooses <i>Up</i>	4, 3	−1, −1
Player 1 chooses <i>Down</i>	0, 0	3, 4

Normal form or payoff matrix of a 2-player, 2-strategy game

General and applied uses

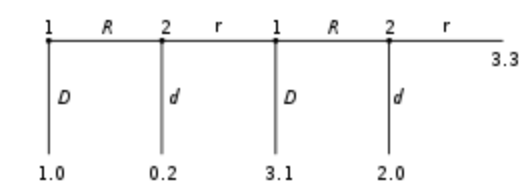
As a method of applied mathematics, game theory has been used to study a wide variety of human and animal behaviors. It was initially developed in economics to understand a large collection of economic behaviors, including behaviors of firms, markets, and consumers. The first use of game-theoretic analysis was by Antoine Augustin Cournot in 1838 with his solution of the Cournot duopoly. The use of game theory in the social sciences has expanded, and game theory has been applied to political, sociological, and psychological behaviors as well.

Although pre-twentieth century naturalists such as Charles Darwin made game-theoretic kinds of statements, the use of game-theoretic analysis in biology began with Ronald Fisher's studies of animal behavior during the 1930s. This work predates the name "game theory", but it shares many important features with this field. The developments in economics were later applied to biology largely by John Maynard Smith in his book *Evolution and the Theory of Games*.^[35]

In addition to being used to describe, predict, and explain behavior, game theory has also been used to develop theories of ethical or normative behavior and to prescribe such behavior.^[36] In economics and philosophy, scholars have applied game theory to help in the understanding of good or proper behavior. Game-theoretic arguments of this type can be found as far back as Plato.^[37] An alternative version of game theory, called chemical game theory, represents the player's choices as metaphorical chemical reactant molecules called “knowlecules”.^[38] Chemical game theory then calculates the outcomes as equilibrium solutions to a system of chemical reactions.

Description and modeling

The primary use of game theory is to describe and model how human populations behave. Some scholars believe that by finding the equilibria of games they can predict how actual human populations will behave when confronted with situations analogous to the game being studied. This particular view of game theory has been criticized. It is argued that the assumptions made by game theorists are often violated when applied to real-world situations. Game theorists usually assume players act rationally, but in practice human behavior often deviates from this model. Game theorists respond by comparing their assumptions to those used in physics. Thus while their assumptions do not always hold, they can treat game theory as a reasonable scientific ideal akin to the models used by physicists. However, empirical work has shown that in some classic games, such as the centipede game, guess 2/3 of the average game, and the dictator game, people regularly do not play Nash equilibria. There is an ongoing debate regarding the importance of these experiments and whether the analysis of the experiments fully captures all aspects of the relevant situation.^[39]



A four-stage centipede game

Some game theorists, following the work of John Maynard Smith and George R. Price, have turned to evolutionary game theory in order to resolve these issues. These models presume either no rationality or bounded rationality on the part of players. Despite the name, evolutionary game theory does not necessarily presume natural selection in the biological sense. Evolutionary game theory includes both biological as well as cultural evolution and also models of individual learning (for example, fictitious play dynamics).

Prescriptive or normative analysis

Some scholars see game theory not as a predictive tool for the behavior of human beings, but as a suggestion for how people ought to behave. Since a strategy, corresponding to a Nash equilibrium of a game constitutes one's best response to the actions of the other players – provided they are in (the same) Nash equilibrium – playing a strategy that is part of a Nash equilibrium seems appropriate. This normative use of game theory has also come under criticism.

	Cooperate	Defect
Cooperate	-1, -1	-10, 0
Defect	0, -10	-1, -1

Economics and business	Defect	0, -10	-5, -5
	<i>The Prisoner's Dilemma</i>		

Game theory is a major method used in mathematical economics and business for modeling competing behaviors of interacting agents.^[40] Applications include a wide array of economic phenomena and approaches, such as auctions, bargaining, mergers & acquisitions pricing,^[41] fair division, duopolies, oligopolies, social network formation, agent-based computational economics,^[42] general equilibrium, mechanism design,^[43] and voting systems;^[44] and across such broad areas as experimental economics,^[45] behavioral economics,^[46] information economics,^[31] industrial organization,^[47] and political economy.^{[48][49]}

This research usually focuses on particular sets of strategies known as "solution concepts" or "equilibria". A common assumption is that players act rationally. In non-cooperative games, the most famous of these is the Nash equilibrium. A set of strategies is a Nash equilibrium if each represents a best response to the other strategies. If all the players are playing the strategies in a Nash equilibrium, they have no unilateral incentive to deviate, since their strategy is the best they can do given what others are doing.^{[50][51]}

The payoffs of the game are generally taken to represent the utility of individual players.

A prototypical paper on game theory in economics begins by presenting a game that is an abstraction of a particular economic situation. One or more solution concepts are chosen, and the author demonstrates which strategy sets in the presented game are equilibria of the appropriate type. Naturally one might wonder to what use this information should be put. Economists and business professors suggest two primary uses (noted above): *descriptive* and *prescriptive*.^[36]

Political science

The application of game theory to political science is focused in the overlapping areas of fair division, political economy, public choice, war bargaining, positive political theory, and social choice theory. In each of these areas, researchers have developed game-theoretic models in which the players are often voters, states, special interest groups, and politicians.

Early examples of game theory applied to political science are provided by Anthony Downs. In his book *An Economic Theory of Democracy*,^[52] he applies the Hotelling firm location model to the political process. In the Downsian model, political candidates commit to ideologies on a one-dimensional policy space. Downs first shows how the political candidates will converge to the ideology preferred by the median voter if voters are fully informed, but then argues that voters choose to remain rationally ignorant which allows for candidate divergence. Game Theory was applied in 1962 to the Cuban missile crisis during the presidency of John F. Kennedy.^[53]

It has also been proposed that game theory explains the stability of any form of political government. Taking the simplest case of a monarchy, for example, the king, being only one person, does not and cannot maintain his authority by personally exercising physical control over all or even any significant number of his subjects. Sovereign control is instead explained by the recognition by each citizen that all other citizens expect each other to view the king (or other established government) as the person whose orders will be followed. Coordinating communication among citizens to replace the sovereign is effectively barred, since conspiracy to replace the sovereign is generally punishable as a crime. Thus, in a process that can be modeled by variants of the prisoner's dilemma, during periods of stability no citizen will find it rational to move to replace the sovereign, even if all the citizens know they would be better off if they were all to act collectively.^[54]

A game-theoretic explanation for democratic peace is that public and open debate in democracies sends clear and reliable information regarding their intentions to other states. In contrast, it is difficult to know the intentions of nondemocratic leaders, what effect concessions will have, and if promises will be kept. Thus there will be mistrust and unwillingness to make concessions if at least one of the parties in a dispute is a non-democracy.^[55]

On the other hand, game theory predicts that two countries may still go to war even if their leaders are cognizant of the costs of fighting. War may result from asymmetric information; two countries may have incentives to mis-represent the amount of military resources they have on hand, rendering them unable to settle disputes agreeably without resorting to fighting. Moreover, war may arise because of commitment problems: if two countries wish to settle a dispute via peaceful means, but each wishes to go back on the terms of that settlement, they may have no choice but to resort to warfare. Finally, war may result from issue indivisibilities.^[56]

Game theory could also help predict a nation's responses when there is a new rule or law to be applied to that nation. One example would be Peter John Wood's (2013) research when he looked into what nations could do to help reduce climate change. Wood thought this could be accomplished by making treaties with other nations to reduce greenhouse gas emissions. However, he concluded that this idea could not work because it would create a prisoner's dilemma to the nations.^[57]

Biology

Unlike those in economics, the payoffs for games in biology are often interpreted as corresponding to fitness. In addition, the focus has been less on equilibria that correspond to a notion of rationality and more on ones that would be maintained by evolutionary forces. The best-known equilibrium in biology is known as the *evolutionarily stable strategy* (ESS), first introduced in (Smith & Price 1973). Although its initial motivation did not involve any of the mental requirements of the Nash equilibrium, every ESS is a Nash equilibrium.

In biology, game theory has been used as a model to understand many different phenomena. It was first used to explain the evolution (and stability) of the approximate 1:1 sex ratios. (Fisher 1930) suggested that the 1:1 sex ratios are a result of evolutionary forces acting on individuals who could be seen as trying to maximize their number of grandchildren.

Additionally, biologists have used evolutionary game theory and the ESS to explain the emergence of animal communication.^[58] The analysis of signaling games and other communication games has provided insight into the evolution of communication among animals. For example, the mobbing behavior of many species, in which a large number of prey animals attack a larger predator, seems to be an example of spontaneous emergent organization. Ants have also been shown to exhibit feed-forward behavior akin to fashion (see Paul Ormerod's *Butterfly Economics*).

Biologists have used the game of chicken to analyze fighting behavior and territoriality.^[59]

According to Maynard Smith, in the preface to *Evolution and the Theory of Games*, "paradoxically, it has turned out that game theory is more readily applied to biology than to the field of economic behaviour for which it was originally designed". Evolutionary game theory has been used to explain many seemingly incongruous phenomena in nature.^[60]

One such phenomenon is known as biological altruism. This is a situation in which an organism appears to act in a way that benefits other organisms and is detrimental to itself. This is distinct from traditional notions of altruism because such actions are not conscious, but appear to be evolutionary adaptations to increase overall fitness. Examples can be found in species ranging from vampire bats that regurgitate blood they have obtained from a night's hunting and give it to group members who have failed to feed, to worker bees that care for the queen bee for their entire lives and never mate, to vervet monkeys that warn group members of a predator's approach, even when it endangers that individual's chance of survival.^[61] All of these actions increase the overall fitness of a group, but occur at a cost to the individual.

Evolutionary game theory explains this altruism with the idea of kin selection. Altruists discriminate between the individuals they help and favor relatives. Hamilton's rule explains the evolutionary rationale behind this selection with the equation $c < b \times r$, where the cost *c* to the altruist must be less than the benefit *b* to the recipient multiplied by the coefficient of relatedness *r*. The more closely related two organisms are causes the incidences of altruism to increase because they share many of the same alleles. This means that the altruistic individual, by ensuring that the alleles of its close relative are passed on through survival of its offspring, can forgo the option of having offspring itself

	Hawk	Dove
Hawk	20, 20	80, 40
Dove	40, 80	60, 60

The hawk-dove game

because the same number of alleles are passed on. For example, helping a sibling (in diploid animals) has a coefficient of ½, because (on average) an individual shares ½ of the alleles in its sibling's offspring. Ensuring that enough of a sibling's offspring survive to adulthood precludes the necessity of the altruistic individual producing offspring.^[61] The coefficient values depend heavily on the scope of the playing field; for example if the choice of whom to favor includes all genetic living things, not just all relatives, we assume the discrepancy between all humans only accounts for approximately 1% of the diversity in the playing field, a coefficient that was ½ in the smaller field becomes 0.995. Similarly if it is considered that information other than that of a genetic nature (e.g. epigenetics, religion, science, etc.) persisted through time the playing field becomes larger still, and the discrepancies smaller.

Computer science and logic

Game theory has come to play an increasingly important role in logic and in computer science. Several logical theories have a basis in game semantics. In addition, computer scientists have used games to model interactive computations. Also, game theory provides a theoretical basis to the field of multi-agent systems.^[62]

Separately, game theory has played a role in online algorithms; in particular, the k-server problem, which has in the past been referred to as *games with moving costs* and *request-answer games*.^[63] Yao's principle is a game-theoretic technique for proving lower bounds on the computational complexity of randomized algorithms, especially online algorithms.

The emergence of the internet has motivated the development of algorithms for finding equilibria in games, markets, computational auctions, peer-to-peer systems, and security and information markets. Algorithmic game theory^[64] and within it algorithmic mechanism design^[65] combine computational algorithm design and analysis of complex systems with economic theory.^[66]

Philosophy

Game theory has been put to several uses in philosophy. Responding to two papers by W.V.O. Quine (1960, 1967), Lewis (1969) used game theory to develop a philosophical account of convention. In so doing, he provided the first analysis of common knowledge and employed it in analyzing play in coordination games. In addition, he first suggested that one can understand meaning in terms of signaling games. This later suggestion has been pursued by several philosophers since Lewis.^[67] Following Lewis (1969) game-theoretic account of conventions, Edna Ullmann-Margalit (1977) and Bicchieri (2006) have developed theories of social norms that define them as Nash equilibria that result from transforming a mixed-motive game into a coordination game.^{[68][69]}

Game theory has also challenged philosophers to think in terms of interactive epistemology: what it means for a collective to have common beliefs or knowledge, and what are the consequences of this knowledge for the social outcomes resulting from the interactions of agents. Philosophers who have worked in this area include Bicchieri (1989, 1993),^{[70][71]} Skyrms (1990),^[72] and Stalnaker (1999).^[73]

In ethics, some (most notably David Gauthier, Gregory Kavka, and Jean Hampton) authors have attempted to pursue Thomas Hobbes' project of deriving morality from self-interest. Since games like the prisoner's dilemma present an apparent conflict between morality and self-interest, explaining why cooperation is required by self-interest is an important component of this project. This general strategy is a component of the general social contract view in political philosophy (for examples, see Gauthier (1986) and Kavka (1986)).^[74]

	Stag	Hare
Stag	3, 3	0, 2
Hare	2, 0	2, 2

Stag hunt

Other authors have attempted to use [evolutionary game theory](#) in order to explain the emergence of human attitudes about morality and corresponding animal behaviors. These authors look at several games including the prisoner's dilemma, [stag hunt](#), and the [Nash bargaining game](#) as providing an explanation for the emergence of attitudes about morality (see, e.g., Skyrms ([1996](#), [2004](#)) and Sober and Wilson ([1999](#))).

In popular culture

- Based on the 1998 book by [Sylvia Nasar](#),^[75] the life story of game theorist and mathematician [John Nash](#) was turned into the 2001 [biopic](#) *[A Beautiful Mind](#)*, starring [Russell Crowe](#) as Nash.^[76]
- The 1959 military science fiction novel *[Starship Troopers](#)* by Robert A. Heinlein mentioned "games theory" and "theory of games".^[77] In the 1997 film of the same name, the character Carl Jenkins referred to his military intelligence assignment as being assigned to "games and theory".
- The 1964 film *[Dr. Strangelove](#)* satirizes game theoretic ideas about deterrence theory. For example, nuclear deterrence depends on the threat to retaliate catastrophically if a nuclear attack is detected. A game theorist might argue that such threats can fail to be *credible*, in the sense that they can lead to [subgame imperfect equilibria](#). The movie takes this idea one step further, with the Russians irrevocably committing to a catastrophic nuclear response without making the threat public.^[78]
- The 1980s [power pop](#) band [Game Theory](#) was founded by singer/songwriter [Scott Miller](#), who described the band's name as alluding to "the study of calculating the most appropriate action given an adversary... to give yourself the minimum amount of failure."^[79]
- [Liar Game](#)*, a 2005 Japanese manga and 2007 television series, presents the main characters in each episode with a game or problem that is typically drawn from game theory, as demonstrated by the strategies applied by the characters.

See also

- | | | |
|---|--|--|
| <ul style="list-style-type: none">Applied ethicsChainstore paradoxChemical game theoryCollective intentionalityCombinatorial game theoryConfrontation analysisGlossary of game theory | <ul style="list-style-type: none">Intra-household bargainingKingmaker scenarioLaw and economicsParrondo's paradoxPrecautionary principleQuantum game theoryQuantum refereed game | <ul style="list-style-type: none">RationalityReverse game theoryRisk managementSelf-confirming equilibriumTragedy of the commonsZermelo's theorem |
|---|--|--|

Lists

- [List of cognitive biases](#)
- [List of emerging technologies](#)
- [List of games in game theory](#)
- [Outline of artificial intelligence](#)

Notes

1. Myerson, Roger B. (1991). <i>Game Theory: Analysis of Conflict</i> , Harvard University Press, p. 1 (https://books.google.com/books?id=E8WQFRCsNr0C&printsec=find&pg=PA1). Chapter-preview links, pp. vii–xi (https://books.google.com/books?id=E8WQFRCsNr0C&printsec=find&pg=PR7).	2. Bellhouse, David (2007), " The Problem of Waldegrave " (http://www.jehps.net/Decembre2007/Bellhouse.pdf) (PDF), <i>Journal Électronique d'Histoire des Probabilités et de la Statistique</i> , 3 (2)
--	--

3. Bellhouse, David R. (2015). "Le Her and Other Problems in Probability Discussed by Bernoulli, Montmort and Waldegrave". *Statistical Science* (Statistical Science Vol. 30, No. 1, 26-39 ed.). Institute Of Mathematical Statistics. **30**: 26–39. [arXiv:1504.01950](https://arxiv.org/abs/1504.01950) (<https://arxiv.org/abs/1504.01950>).
[Bibcode:2015arXiv150401950B](https://ui.adsabs.harvard.edu/abs/2015arXiv150401950B) (<https://ui.adsabs.harvard.edu/abs/2015arXiv150401950B>). doi:10.1214/14-STS469 (<https://doi.org/10.1214%2F14-STS469>).
4. https://socio.ethz.ch/content/dam/ethz/special-interest/gess/chair-of-sociology-dam/documents/articles/Zermelo_Uber_eine_Anwendung_der_Mengenlehre_auf_die_Theorie_des_Schachspiels.pdf Archived (https://web.archive.org/web/20151023075458/http://www.socio.ethz.ch/content/dam/ethz/special-interest/gess/chair-of-sociology-dam/documents/articles/Zermelo_Uber_eine_Anwendung_der_Mengenlehre_auf_die_Theorie_des_Schachspiels.pdf) 23 October 2015 at the [Wayback Machine](https://www.webcitation.org/5WzGwS8Gw) | German Translation of Ernst Zermelo's (1913) 'On an Application of Set Theory to the Theory of the Game of Chess'
5. Kim, Sungwook, ed. (2014). *Game theory applications in network design* (<https://books.google.com/books?id=phOXBQAAQBAJ&pg=PA3>). IGI Global. p. 3. ISBN 9781466660519.
6. Neumann, J. v. (1928), "Zur Theorie der Gesellschaftsspiele", *Mathematische Annalen*, **100** (1): 295–320, doi:10.1007/BF01448847 (<https://doi.org/10.1007%2FBF01448847>) English translation: Tucker, A. W.; Luce, R. D., eds. (1959), "On the Theory of Games of Strategy" (<https://books.google.com/books?id=9ISVFzsTGWsC&pg=PA13>), *Contributions to the Theory of Games*, **4**, pp. 13–42
7. Mirowski, Philip (1992). "What Were von Neumann and Morgenstern Trying to Accomplish?" (<https://books.google.com/books?id=9CHY2Gozh1MC&pg=PA113>). In Weintraub, E. Roy (ed.). *Toward a History of Game Theory*. Durham: Duke University Press. pp. 113–147. ISBN 978-0-8223-1253-6.
8. Leonard, Robert (2010), *Von Neumann, Morgenstern, and the Creation of Game Theory*, New York: Cambridge University Press, ISBN 9780521562669
9. Prisoner's Dilemma (<http://plato.stanford.edu/entries/prisoner-dilemma/>). Plato.stanford.edu (4 September 1997). Retrieved on 3 January 2013.
10. Wolfram, Stephen (2002). *A New Kind of Science* (<https://archive.org/details/newkindofscience00wolf>). Wolfram Media, Inc. p. 1104. ISBN 978-1-57955-008-0.
11. Although common knowledge was first discussed by the philosopher [David Lewis](#) in his dissertation (and later book) *Convention* in the late 1960s, it was not widely considered by economists until [Robert Aumann](#)'s work in the 1970s.
12. Owen, Guillermo (1995). *Game Theory: Third Edition*. Bingley: Emerald Group Publishing. p. 11. ISBN 978-0-12-531151-9.
13. Ferguson, Thomas S. "Game Theory" (https://www.math.ucla.edu/~tom/Game_Theory/mat.pdf#page=56) (PDF). UCLA Department of Mathematics. pp. 56–57.
14. "Complete vs Perfect Infomation in Combinatorial Game Theory" (<https://math.stackexchange.com/q/845452>). *Stack Exchange*. 24 June 2014.
15. Mycielski, Jan (1992). "Games with Perfect Information". *Handbook of Game Theory with Economic Applications*. Volume 1. pp. 41–70. doi:10.1016/S1574-0005(05)80006-2 (<https://doi.org/10.1016%2FS1574-0005%2805%2980006-2>). ISBN 9780444880987.
16. "Infinite Chess" (<https://www.youtube.com/watch?v=PN-l6u-AxMg&t=0m25s>). *PBS Infinite Series*. 2 March 2017. Perfect information defined at 0:25, with academic sources [arXiv:1302.4377](https://arxiv.org/abs/1302.4377) and [arXiv:1510.08155](https://arxiv.org/abs/1510.08155).
17. Owen, Guillermo (1995). *Game Theory: Third Edition*. Bingley: Emerald Group Publishing. p. 4. ISBN 978-0-12-531151-9.
18. Leyton-Brown & Shoham (2008), p. 60.
19. Jörg Bewersdorff (2005), *Luck, logic, and white lies: the mathematics of games*, A K Peters, Ltd., pp. ix–xii and chapter 31, ISBN 978-1-56881-210-6
20. Albert, Michael H.; Nowakowski, Richard J.; Wolfe, David (2007), *Lessons in Play: In Introduction to Combinatorial Game Theory*, A K Peters Ltd, pp. 3–4, ISBN 978-1-56881-277-9
21. Beck, József (2008), *Combinatorial games: tic-tac-toe theory*, Cambridge University Press, pp. 1–3, ISBN 978-0-521-46100-9
22. Robert A. Hearn; Erik D. Demaine (2009), *Games, Puzzles, and Computation*, A K Peters, Ltd., ISBN 978-1-56881-322-6
23. M. Tim Jones (2008), *Artificial Intelligence: A Systems Approach*, Jones & Bartlett Learning, pp. 106–118, ISBN 978-0-7637-7337-3
24. (in Russian) Petrosjan, L.A. and Murzov, N.V. (1966). *Game-theoretic problems of mechanics*. *Litovsk. Mat. Sb.* 6, 423–433.
25. Newton, Jonathan (2018). "Evolutionary Game Theory: A Renaissance". *Games*. **9** (2): 31. doi:10.3390/g9020031 (<https://doi.org/10.3390%2Fg9020031>).
26. Webb (2007).
27. Osborne & Rubinstein (1994).
28. Hugh Brendan McMahan (2006), *Robust Planning in Domains with Stochastic Outcomes, Adversaries, and Partial Observability* (https://www.cs.cmu.edu/~mcmahan/research/mcmahan_thesis.pdf), CMU-CS-06-166, pp. 3–4
29. Howard (1971).
30. Wenliang Wang (2015). Pooling Game Theory and Public Pension Plan. ISBN 978-1507658246.

31.
 - Eric Rasmusen (2007). *Games and Information*, 4th ed. Description (<http://www.wiley.com/WileyCDA/WileyTitle/productCd-EHEP001009.html>) and chapter-preview. (<https://books.google.com/books?id=5XEMuJwnBmUC&pg=PR5>)
 - David M. Kreps (1990). *Game Theory and Economic Modelling*. Description. (<http://econpapers.repec.org/bookchap/oxpobooks/9780198283812.htm>)
 - <http://www.sciencedirect.com/science/handbooks/15740005/1> (<http://www.sciencedirect.com/science/handbooks/15740005/1>). Missing or empty |title= (help)
 - Aumann, Robert J.; Heifetz, Aviad (2002). "Chapter 43 Incomplete information". *Handbook of Game Theory with Economic Applications Volume 3*. *Handbook of Game Theory with Economic Applications*. **3**. pp. 1665–1686. doi:10.1016/S1574-0005(02)03006-0 (<https://doi.org/10.1016%2FS1574-0005%2802%2903006-0>). ISBN 9780444894281.
32. Fudenberg & Tirole (1991), p. 67.
33. Williams, Paul D. (2013). *Security Studies: an Introduction (second edition)*. 2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN: Routledge. pp. 55–56.
34. Leyton-Brown & Shoham (2008), p. 35.
35. "On economic applications of evolutionary game theory" (<https://leeps.ucsc.edu/media/papers/EconAppEvolGameTheory3-1-98.pdf>) (PDF). *J Evol Econ*.
36. Colin F. Camerer (2003). *Behavioral Game Theory: Experiments in Strategic Interaction*, pp. 5–7 (scroll to at 1.1 What Is Game Theory Good For? (<http://press.princeton.edu/chapters/i7517.html>) Archived (<https://web.archive.org/web/20110514201411/http://press.princeton.edu/chapters/i7517.html>) 14 May 2011 at the Wayback Machine).
37. Ross, Don. "Game Theory" (<http://plato.stanford.edu/archives/spr2008/entries/game-theory/>). *The Stanford Encyclopedia of Philosophy (Spring 2008 Edition)*. Edward N. Zalta (ed.). Retrieved 21 August 2008.
38. Velegol, Darrell; Suhey, Paul; Connolly, John; Morrissey, Natalie; Cook, Laura (14 September 2018). "Chemical Game Theory". *Industrial & Engineering Chemistry Research*. **57** (41): 13593–13607. doi:10.1021/acs.iecr.8b03835 (<https://doi.org/10.1021%2Facs.iecr.8b03835>). ISSN 0888-5885 (<https://www.worldcat.org/issn/0888-5885>).
39. Experimental work in game theory goes by many names, experimental economics, behavioral economics, and behavioural game theory are several. For a recent discussion, see Colin F. Camerer (2003). *Behavioral Game Theory: Experiments in Strategic Interaction* (description (<http://press.princeton.edu/titles/7517.html>) and Introduction (<http://press.princeton.edu/chapters/i7517.html>) Archived (<https://web.archive.org/web/20110514201411/http://press.princeton.edu/chapters/i7517.html>) 14 May 2011 at the Wayback Machine, pp. 1–25).
40.
 - At JEL:C7 of the *Journal of Economic Literature* classification codes.
 - R.J. Aumann (2008). "game theory," *The New Palgrave Dictionary of Economics*, 2nd Edition. Abstract. (http://www.dictionaryofeconomics.com/article?id=pde2008_G000007&edition=current&q=game%20theory&topicid=&result_number=4) Archived (https://web.archive.org/web/20110515034120/http://www.dictionaryofeconomics.com/article?id=pde2008_G000007&edition=current&q=game%20theory&topicid=&result_number=4) 15 May 2011 at the Wayback Machine
 - Martin Shubik (1981). "Game Theory Models and Methods in Political Economy," in Kenneth Arrow and Michael Intriligator, ed., *Handbook of Mathematical Economics*, v. 1, pp. 285–330 doi:10.1016/S1573-4382(81)01011-4 (<https://doi.org/10.1016%2FS1573-4382%2881%2901011-4>).
 - Carl Shapiro (1989). "The Theory of Business Strategy," *RAND Journal of Economics*, 20(1), pp. 125–137 JSTOR 2555656 (<https://www.jstor.org/stable/2555656>).
41. N. Agarwal and P. Zeepongsekul. Psychological Pricing in Mergers & Acquisitions using Game Theory (<http://www.mssanz.org.au/modsim2011/D6/agarwal.pdf>), School of Mathematics and Geospatial Sciences, RMIT University, Melbourne
42.
 - Leigh Tesfatsion (2006). "Agent-Based Computational Economics: A Constructive Approach to Economic Theory," ch. 16, *Handbook of Computational Economics*, v. 2, pp. 831–880 doi:10.1016/S1574-0021(05)02016-2 (<https://doi.org/10.1016%2FS1574-0021%2805%2902016-2>).
 - Joseph Y. Halpern (2008). "computer science and game theory," *The New Palgrave Dictionary of Economics*, 2nd Edition. Abstract (http://www.dictionaryofeconomics.com/article?id=pde2008_C000566&edition=current&topicid=&result_number=1).

43. • From *The New Palgrave Dictionary of Economics* (2008), 2nd Edition:
Roger B. Myerson. "mechanism design." Abstract (http://www.dictionaryofeconomics.com/article?id=pde2008_M000132&edition=current&q=mechanism%20design&topicid=&result_number=3) Archived (https://web.archive.org/web/20111123042038/http://www.dictionaryofeconomics.com/article?id=pde2008_M000132&edition=current&q=mechanism%20design&topicid=&result_number=3) 23 November 2011 at the Wayback Machine.
_____. "revelation principle." Abstract (http://www.dictionaryofeconomics.com/article?id=pde2008_R000137&edition=current&q=moral&topicid=&result_number=1).
• Tuomas Sandholm. "computing in mechanism design." Abstract. (http://www.dictionaryofeconomics.com/article?id=pde2008_C000563&edition=&field=keyword&q=algorithmic%20mechanism%20design&topicid=&result_number=1) Archived (https://web.archive.org/web/20111123042038/http://www.dictionaryofeconomics.com/article?id=pde2008_C000563&edition=&field=keyword&q=algorithmic%20mechanism%20design&topicid=&result_number=1) 23 November 2011 at the Wayback Machine
• Noam Nisan and Amir Ronen (2001). "Algorithmic Mechanism Design," *Games and Economic Behavior*, 35(1–2), pp. 166–196 (<https://www.cs.cmu.edu/~sandholm/cs15-892F09/Algorithmic%20mechanism%20design.pdf>).
• Noam Nisan *et al.*, ed. (2007). *Algorithmic Game Theory*, Cambridge University Press. Description (<http://www.cup.cam.ac.uk/asia/catalogue/catalogue.asp?isbn=9780521872829>) Archived (<https://web.archive.org/web/20120505140924/http://www.cup.cam.ac.uk/asia/catalogue/catalogue.asp?isbn=9780521872829>) 5 May 2012 at the Wayback Machine .
44. Brams, Steven J. (1994). *Chapter 30 Voting procedures*. Handbook of Game Theory with Economic Applications. 2. pp. 1055–1089. doi:10.1016/S1574-0005(05)80062-1 (<https://doi.org/10.1016%2FS1574-0005%2805%2980062-1>). ISBN 9780444894274. and Moulin, Hervé (1994). *Chapter 31 Social choice*. Handbook of Game Theory with Economic Applications. 2. pp. 1091–1125. doi:10.1016/S1574-0005(05)80063-3 (<https://doi.org/10.1016%2FS1574-0005%2805%2980063-3>). ISBN 9780444894274.
45. ■ Vernon L. Smith, 1992. "Game Theory and Experimental Economics: Beginnings and Early Influences," in E. R. Weintraub, ed., *Towards a History of Game Theory*, pp. 241–282 (<https://books.google.com/books?id=9CHY2GoZh1MC&pg=PA241>)
■ Smith, V.L. (2001). "Experimental Economics". *International Encyclopedia of the Social & Behavioral Sciences*. pp. 5100–5108. doi:10.1016/B0-08-043076-7/02232-4 (<https://doi.org/10.1016%2FB0-08-043076-7%2F02232-4>). ISBN 9780080430768.
■ <http://www.sciencedirect.com/science/handbooks/15740722> (<http://www.sciencedirect.com/science/handbooks/15740722>). Missing or empty `|title=` (help)
■ Vincent P. Crawford (1997). "Theory and Experiment in the Analysis of Strategic Interaction," in *Advances in Economics and Econometrics: Theory and Applications*, pp. 206–242 (<http://weber.ucsd.edu/~vcrawfor/CrawfordTheExp97.pdf>). Cambridge. Reprinted in Colin F. Camerer *et al.*, ed. (2003). *Advances in Behavioral Economics*, Princeton. 1986–2003 papers. Description (<http://press.princeton.edu/titles/8437.html>), preview (<https://books.google.com/books?id=sA4jJOjwCW4C&printsec=find&pg=PR7>), Princeton, ch. 12.
■ Shubik, Martin (2002). "Chapter 62 Game theory and experimental gaming". *Handbook of Game Theory with Economic Applications Volume 3*. Handbook of Game Theory with Economic Applications. 3. pp. 2327–2351. doi:10.1016/S1574-0005(02)03025-4 (<https://doi.org/10.1016%2FS1574-0005%2802%2903025-4>). ISBN 9780444894281.

46. From *The New Palgrave Dictionary of Economics* (2008), 2nd Edition:
 - Faruk Gul. "behavioural economics and game theory." Abstract. (http://www.dictionaryofeconomics.com/article?id=pde2008_G000210&q=Behavioral%20economics%20&topicid=&result_number=2)
 - Colin F. Camerer. "behavioral game theory." Abstract. (http://www.dictionaryofeconomics.com/article?id=pde2008_B000302&q=Behavioral%20economics%20&topicid=&result_number=13) Archived (https://web.archive.org/web/20111123034346/http://www.dictionaryofeconomics.com/article?id=pde2008_B000302&q=Behavioral%20economics%20&topicid=&result_number=13) 23 November 2011 at the [Wayback Machine](#)
 - _____ (1997). "Progress in Behavioral Game Theory," *Journal of Economic Perspectives*, 11(4), p. 172, pp. 167–188 (<http://authors.library.caltech.edu/22122/1/2138470%5B1%5D.pdf>).
 - _____ (2003). *Behavioral Game Theory*, Princeton. Description (<http://press.princeton.edu/chapters/i7517.html>) Archived (<https://web.archive.org/web/20110514201411/http://press.princeton.edu/chapters/i7517.html>) 14 May 2011 at the [Wayback Machine](#), preview (https://books.google.com/books?id=cr_Xg7cRvdcC&printsec=find&pg=PR7) ([ctrl]+), and ch. 1 link (<http://press.princeton.edu/chapters/i7517.pdf>).
 - _____, George Loewenstein, and Matthew Rabin, ed. (2003). *Advances in Behavioral Economics*, Princeton. 1986–2003 papers. Description (<http://press.princeton.edu/titles/8437.html>), contents (<https://books.google.com/books?id=sA4jJOjwCW4C&printsec=find&pg=PR7>), and preview (<https://books.google.com/books?id=sA4jJOjwCW4C&printsec=find&pg=PR7>).
 - Drew Fudenberg (2006). "Advancing Beyond *Advances in Behavioral Economics*," *Journal of Economic Literature*, 44(3), pp. 694–711 JSTOR 30032349 (<https://www.jstor.org/stable/30032349>).
47. • Jean Tirole (1988). *The Theory of Industrial Organization*, MIT Press. Description (<https://books.google.com/books?id=HljsF0XONF8C>) and chapter-preview links, pp. vii–ix (<https://books.google.com/books?id=HljsF0XONF8C&printsec=find&pg=PR7>), "General Organization," pp. 5–6 (<https://books.google.com/books?id=HljsF0XONF8C&pg=PA5>), and "Non-Cooperative Game Theory: A User's Guide Manual," ch. 11, pp. 423–59 (<https://books.google.com/books?id=HljsF0XONF8C&pg=PA423>).
 - Kyle Bagwell and Asher Wolinsky (2002). "Game theory and Industrial Organization," ch. 49, *Handbook of Game Theory with Economic Applications*, v. 3, pp. 1851–1895 (<http://www.sciencedirect.com/science/article/pii/S1574000502030126>).
 - Martin Shubik (1959). *Strategy and Market Structure: Competition, Oligopoly, and the Theory of Games*, Wiley. Description (<http://devirevues.demon.inist.fr/handle/2042/29380>) and review extract (<https://www.jstor.org/pss/40434883>).
 - _____ with Richard Levitan (1980). *Market Structure and Behavior*, Harvard University Press. Review extract (<https://www.jstor.org/pss/2232276>). Archived (<https://web.archive.org/web/20100315131945/http://mitpress.mit.edu/catalog/item/default.asp?tttype=2&tid=8224>) 15 March 2010 at the [Wayback Machine](#)
48. • Martin Shubik (1981). "Game Theory Models and Methods in Political Economy," in *Handbook of Mathematical Economics*, v. 1, pp. 285–330 doi:[10.1016/S1573-4382\(81\)01011-4](https://doi.org/10.1016/S1573-4382(81)01011-4) (<https://doi.org/10.1016%2FS1573-4382%2881%2901011-4>).
 - _____ (1987). *A Game-Theoretic Approach to Political Economy*. MIT Press. Description (<http://mitpress.mit.edu/catalog/item/default.asp?tid=5086&tttype=2>). Archived (<https://web.archive.org/web/20110629151809/http://mitpress.mit.edu/catalog/item/default.asp?tid=5086&tttype=2>) 29 June 2011 at the [Wayback Machine](#)
49. • Martin Shubik (1978). "Game Theory: Economic Applications," in W. Kruskal and J.M. Tanur, ed., *International Encyclopedia of Statistics*, v. 2, pp. 372–78.
 - Robert Aumann and Sergiu Hart, ed. *Handbook of Game Theory with Economic Applications* (scrollable to chapter-outline or abstract links):
 - 1992. v. 1 (<http://www.sciencedirect.com/science/handbooks/15740005/1>);
 - 1994. v. 2 (<http://www.sciencedirect.com/science/handbooks/15740005/2>);
 - 2002. v. 3. (<http://www.sciencedirect.com/science/handbooks/15740005/3>)
50. Game-theoretic model to examine the two tradeoffs in the acquisition of information for a careful balancing act (<http://www.insead.edu/facultyresearch/research/doc.cfm?did=46503>) Archived (<https://web.archive.org/web/20130524231021/http://www.insead.edu/facultyresearch/research/doc.cfm?did=46503>) 24 May 2013 at the [Wayback Machine](#) Research paper [INSEAD](#)
51. Options Games: Balancing the trade-off between flexibility and commitment (<http://web.archive.org/web/20140327103727/http://www.europeanfinancialreview.com/?p=4645>) Archived (<https://web.archive.org/web/20130620053305/http://www.europeanfinancialreview.com/?p=4645>) 20 June 2013 at the [Wayback Machine](#). [Europeanfinancialreview.com](http://www.europeanfinancialreview.com) (15 February 2012). Retrieved on 2013-01-03.
52. (Downs 1957)

53. Steven J. Brams, Game theory and the Cuban missile crisis (<https://plus.maths.org/content/game-theory-and-cuban-missile-crisis>), Plus Magazine, 1 January 2001, accessed 31 January 2016.
54. Morrison, A. S. (2013). "Yes, Law is the Command of the Sovereign". doi:10.2139/ssrn.2371076 (<https://doi.org/10.2139%2Fssrn.2371076>).
55. Levy, G.; Razin, R. (2004). "It Takes Two: An Explanation for the Democratic Peace" (<http://eprints.lse.ac.uk/539/>). *Journal of the European Economic Association*. **2** (1): 1–29. doi:10.1162/154247604323015463 (<https://doi.org/10.1162%2F154247604323015463>). JSTOR 40004867 (<https://www.jstor.org/stable/40004867>).
56. Fearon, James D. (1 January 1995). "Rationalist Explanations for War". *International Organization*. **49** (3): 379–414. doi:10.1017/s0020818300033324 (<https://doi.org/10.1017%2Fs0020818300033324>). JSTOR 2706903 (<https://www.jstor.org/stable/2706903>).
57. Wood, Peter John (2011). "Climate change and game theory" (https://crawford.anu.edu.au/research_units/eeerh/pdf/EERH_RR62.pdf) (PDF). *Ecological Economics Review*. **1219** (1): 153–70. Bibcode:2011NYASA1219..153W (<https://ui.adsabs.harvard.edu/abs/2011NYASA1219..153W>). doi:10.1111/j.1749-6632.2010.05891.x (<https://doi.org/10.1111%2Fj.1749-6632.2010.05891.x>). hdl:1885/67270 (<https://hdl.handle.net/1885%2F67270>). PMID 21332497 (<https://www.ncbi.nlm.nih.gov/pubmed/21332497>).
58. Harper & Maynard Smith (2003).
59. Maynard Smith, J. (1974). "The theory of games and the evolution of animal conflicts" (<http://www.dklevine.com/archive/refs4448.pdf>) (PDF). *Journal of Theoretical Biology*. **47** (1): 209–221. doi:10.1016/0022-5193(74)90110-6 (<https://doi.org/10.1016%2F0022-5193%2874%2990110-6>). PMID 4459582 (<https://www.ncbi.nlm.nih.gov/pubmed/4459582>).
60. Evolutionary Game Theory (Stanford Encyclopedia of Philosophy) (<http://plato.stanford.edu/entries/game-evolutionary/>). Plato.stanford.edu. Retrieved on 3 January 2013.
61. Biological Altruism (Stanford Encyclopedia of Philosophy) (<http://www.seop.leeds.ac.uk/entries/altruism-biological/>). Seop.leeds.ac.uk. Retrieved on 3 January 2013.
62. Yoav Shoham; Kevin Leyton-Brown (15 December 2008). *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations* (https://books.google.com/books?id=bMR_qScakukC&printsec=frontcover#v=onepage&q=%22game%20theory%22&f=false). Cambridge University Press. ISBN 978-1-139-47524-2.
63. (Ben David, Borodin & Karp et al. 1994)
64. Noam Nisan et al., ed. (2007). *Algorithmic Game Theory*, Cambridge University Press. Description (<http://www.cup.cam.ac.uk/asia/catalogue/catalogue.asp?isbn=9780521872829>). Archived (<https://web.archive.org/web/20120505140924/http://www.cup.cam.ac.uk/asia/catalogue/catalogue.asp?isbn=9780521872829>) 5 May 2012 at the Wayback Machine
65. Nisan, Noam; Ronen, Amir (2001), "Algorithmic Mechanism Design" (<https://www.cs.cmu.edu/~sandholm/cs15-892F09/Algorithmic%20mechanism%20design.pdf>) (PDF), *Games and Economic Behavior*, **35** (1–2): 166–196, CiteSeerX 10.1.1.21.1731 (<https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.21.1731>), doi:10.1006/game.1999.0790 (<https://doi.org/10.1006%2Fgame.1999.0790>)
66. • Joseph Y. Halpern (2008). "computer science and game theory," *The New Palgrave Dictionary of Economics*, 2nd Edition. Abstract (http://www.dictionaryofeconomics.com/article?id=pde2008_C000566&edition=current&topicid=&result_number=1).
 - Shoham, Yoav (2008), "Computer Science and Game Theory" (<http://www.robotics.stanford.edu/~shoham/www%20papers/CSGT-CACM-Shoham.pdf>) (PDF), *Communications of the ACM*, **51** (8): 75–79, CiteSeerX 10.1.1.314.2936 (<https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.314.2936>), doi:10.1145/1378704.1378721 (<https://doi.org/10.1145%2F1378704.1378721>)
 - Littman, Amy; Littman, Michael L. (2007), "Introduction to the Special Issue on Learning and Computational Game Theory", *Machine Learning*, **67** (1–2): 3–6, doi:10.1007/s10994-007-0770-1 (<https://doi.org/10.1007%2Fs10994-007-0770-1>)
67. (Skyrms (1996), Grim, Kokalis, and Alai-Tafti et al. (2004)).
68. Ullmann-Margalit, E. (1977), *The Emergence of Norms* (<https://archive.org/details/emergenceofnorms0024ullm>), Oxford University Press, ISBN 978-0198244110
69. Bicchieri, C. (2006), *The Grammar of Society: the Nature and Dynamics of Social Norms*, Cambridge University Press, ISBN 978-0521573726
70. Bicchieri, Cristina (1989), "Self-Refuting Theories of Strategic Interaction: A Paradox of Common Knowledge", *Erkenntnis*, **30** (1–2): 69–85, doi:10.1007/BF00184816 (<https://doi.org/10.1007%2FBF00184816>)
71. Bicchieri, Cristina (1993), *Rationality and Coordination*, Cambridge University Press, ISBN 978-0-521-57444-0
72. *The Dynamics of Rational Deliberation*, Harvard University Press, 1990, ISBN 978-0674218857
73. Bicchieri, Cristina; Jeffrey, Richard; Skyrms, Brian, eds. (1999), "Knowledge, Belief, and Counterfactual Reasoning in Games", *The Logic of Strategy*, New York: Oxford University Press, ISBN 978-0195117158
74. For a more detailed discussion of the use of game theory in ethics, see the Stanford Encyclopedia of Philosophy's entry game theory and ethics (<http://plato.stanford.edu/entries/game-ethics/>).
75. Nasar, Sylvia (1998) *A Beautiful Mind*, Simon & Schuster. ISBN 0-684-81906-6.

76. Singh, Simon (14 June 1998) "Between Genius and Madness" (<https://www.nytimes.com/books/98/06/14/reviews/980614.14singht.html>), New York Times.
77. Heinlein, Robert A. (1959), *Starship Troopers*
78. *Dr. Strangelove Or How I Learned to Stop Worrying and Love the Bomb* (https://archive.org/details/DRStrangelove_20130616). 29 January 1964. 51 minutes in. "... is that the whole point of the doomsday machine is lost, if you keep it a secret!"

79. Guzman, Rafer (6 March 1996). "Star on hold: Faithful following, meager sales" (https://web.archive.org/web/20131106223809/http://www.loudfamily.com/old/intpac_sun.html). *Pacific Sun*. Archived from the original (<http://www.loudfamily.com/old/intpacsun.html>) on 6 November 2013. Retrieved 25 July 2018..

Cite error: A list-defined reference named "ohet" is not used in the content (see the [help page](#)).

References and further reading

Textbooks and general references

- Aumann, Robert J (1987), "game theory", *The New Palgrave: A Dictionary of Economics*, **2**, pp. 460–82.
- Camerer, Colin (2003), "Introduction" (<http://press.princeton.edu/chapters/i7517.html>), *Behavioral Game Theory: Experiments in Strategic Interaction*, Russell Sage Foundation, pp. 1–25, ISBN 978-0-691-09039-9, Description (<http://press.princeton.edu/titles/7517.html>).
- Dutta, Prajit K. (1999), *Strategies and games: theory and practice*, MIT Press, ISBN 978-0-262-04169-0. Suitable for undergraduate and business students. <https://b-ok.org/book/2640653/e56341>.
- Fernandez, L F.; Bierman, H S. (1998), *Game theory with economic applications*, Addison-Wesley, ISBN 978-0-201-84758-1. Suitable for upper-level undergraduates.
- Gibbons, Robert D. (1992), *Game theory for applied economists*, Princeton University Press, ISBN 978-0-691-00395-5. Suitable for advanced undergraduates.
 - Published in Europe as Gibbons, Robert (2001), *A Primer in Game Theory*, London: Harvester Wheatsheaf, ISBN 978-0-7450-1159-2.
- Gintis, Herbert (2000), *Game theory evolving: a problem-centered introduction to modeling strategic behavior*, Princeton University Press, ISBN 978-0-691-00943-8
- Green, Jerry R.; Mas-Colell, Andreu; Whinston, Michael D. (1995), *Microeconomic theory*, Oxford University Press, ISBN 978-0-19-507340-9. Presents game theory in formal way suitable for graduate level.
- Joseph E. Harrington (2008) *Games, strategies, and decision making*, Worth, ISBN 0-7167-6630-2. Textbook suitable for undergraduates in applied fields; numerous examples, fewer formalisms in concept presentation.
- Howard, Nigel (1971), *Paradoxes of Rationality: Games, Metagames, and Political Behavior*, Cambridge, MA: The MIT Press, ISBN 978-0-262-58237-7
- Isaacs, Rufus (1999), *Differential Games: A Mathematical Theory With Applications to Warfare and Pursuit, Control and Optimization*, New York: Dover Publications, ISBN 978-0-486-40682-4
- Miller, James H. (2003), *Game theory at work: how to use game theory to outthink and outmaneuver your competition*, New York: McGraw-Hill, ISBN 978-0-07-140020-6. Suitable for a general audience.
- Osborne, Martin J. (2004), *An introduction to game theory*, Oxford University Press, ISBN 978-0-19-512895-6. Undergraduate textbook.
- Osborne, Martin J.; Rubinstein, Ariel (1994), *A course in game theory*, MIT Press, ISBN 978-0-262-65040-3. A modern introduction at the graduate level.
- Shoham, Yoav; Leyton-Brown, Kevin (2009), *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations* (<http://www.masfoundations.org/download.html>), New York: Cambridge University Press, ISBN 978-0-521-89943-7, retrieved 8 March 2016
- Roger McCain's Game Theory: A Nontechnical Introduction to the Analysis of Strategy (<http://www.economics.harvard.edu/~aroth/alroth.html/top/econo/game/game.html>) (Revised Edition)
- Webb, James N. (2007), *Game theory: decisions, interaction and evolution*, Undergraduate mathematics, Springer, ISBN 978-1-84628-423-6 Consistent treatment of game types usually claimed by different applied fields, e.g. [Markov decision processes](#).

Historically important texts

- Aumann, R.J. and Shapley, L.S. (1974), *Values of Non-Atomic Games*, Princeton University Press

- Cournot, A. Augustin (1838), "Recherches sur les principes mathématiques de la théorie des richesses", *Librairie des Sciences Politiques et Sociales*
- Edgeworth, Francis Y. (1881), *Mathematical Psychics* (<https://books.google.com/books?id=CEIYAAAAcAAJ&printsec=frontcover#v=onepage>), London: Kegan Paul
- Farquharson, Robin (1969), *Theory of Voting*, Blackwell (Yale U.P. in the U.S.), ISBN 978-0-631-12460-3
- Luce, R. Duncan; Raiffa, Howard (1957), *Games and decisions: introduction and critical survey*, New York: Wiley
 - reprinted edition: R. Duncan Luce ; Howard Raiffa (1989), *Games and decisions: introduction and critical survey*, New York: Dover Publications, ISBN 978-0-486-65943-5
- Maynard Smith, John (1982), *Evolution and the theory of games*, Cambridge University Press, ISBN 978-0-521-28884-2
- Maynard Smith, John; Price, George R. (1973), "The logic of animal conflict", *Nature*, **246** (5427): 15–18, Bibcode:1973Natur.246...15S (<https://ui.adsabs.harvard.edu/abs/1973Natur.246...15S>), doi:10.1038/246015a0 (<https://doi.org/10.1038%2F246015a0>)
- Nash, John (1950), "Equilibrium points in n-person games", *Proceedings of the National Academy of Sciences of the United States of America*, **36** (1): 48–49, Bibcode:1950PNAS...36...48N (<https://ui.adsabs.harvard.edu/abs/1950PNAS...36...48N>), doi:10.1073/pnas.36.1.48 (<https://doi.org/10.1073%2Fpnas.36.1.48>), PMC 1063129 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1063129>), PMID 16588946 (<https://www.ncbi.nlm.nih.gov/pubmed/16588946>)
- Shapley, L.S. (1953), A Value for n-person Games, In: Contributions to the Theory of Games volume II, H. W. Kuhn and A. W. Tucker (eds.)
- Shapley, L.S. (1953), Stochastic Games, Proceedings of National Academy of Science Vol. 39, pp. 1095–1100.
- von Neumann, John (1928), "Zur Theorie der Gesellschaftsspiele", *Mathematische Annalen*, **100** (1): 295–320, doi:10.1007/bf01448847 (<https://doi.org/10.1007%2Fbf01448847>) English translation: "On the Theory of Games of Strategy," in A. W. Tucker and R. D. Luce, ed. (1959), *Contributions to the Theory of Games*, v. 4, p. 42. (<https://books.google.com/books?id=9ISVFzsTGWsC&pg=PA42>) Princeton University Press.
- von Neumann, John; Morgenstern, Oskar (1944), "Theory of games and economic behavior", *Nature*, Princeton University Press, **157** (3981): 172, Bibcode:1946Natur.157..172R (<https://ui.adsabs.harvard.edu/abs/1946Natur.157..172R>), doi:10.1038/157172a0 (<https://doi.org/10.1038%2F157172a0>)
- Zermelo, Ernst (1913), "Über eine Anwendung der Mengenlehre auf die Theorie des Schachspiels", *Proceedings of the Fifth International Congress of Mathematicians*, **2**: 501–4

Other print references

- Ben David, S.; Borodin, Allan; Karp, Richard; Tardos, G.; Wigderson, A. (1994), "On the Power of Randomization in On-line Algorithms" (<http://www.math.ias.edu/~avi/PUBLICATIONS/MYPAPERS/BORODIN/paper.pdf>) (PDF), *Algorithmica*, **11** (1): 2–14, doi:10.1007/BF01294260 (<https://doi.org/10.1007%2FBF01294260>)
- Downs, Anthony (1957), *An Economic theory of Democracy*, New York: Harper
- Gauthier, David (1986), *Morals by agreement*, Oxford University Press, ISBN 978-0-19-824992-4
- Allan Gibbard, "Manipulation of voting schemes: a general result", *Econometrica*, Vol. 41, No. 4 (1973), pp. 587–601.
- Grim, Patrick; Kokalis, Trina; Alai-Tafti, Ali; Kilb, Nicholas; St Denis, Paul (2004), "Making meaning happen", *Journal of Experimental & Theoretical Artificial Intelligence*, **16** (4): 209–243, doi:10.1080/09528130412331294715 (<https://doi.org/10.1080%2F09528130412331294715>)
- Harper, David; Maynard Smith, John (2003), *Animal signals*, Oxford University Press, ISBN 978-0-19-852685-8
- Lewis, David (1969), *Convention: A Philosophical Study*, ISBN 978-0-631-23257-5 (2002 edition)
- McDonald, John (1950–1996), *Strategy in Poker, Business & War*, W. W. Norton, ISBN 978-0-393-31457-1. A layman's introduction.
- Papayouanou, Paul (2010), *Game Theory for Business: A Primer in Strategic Gaming*, Probabilistic, ISBN 978-0964793873.
- Quine, W.v.O (1967), "Truth by Convention", *Philosophica Essays for A.N. Whitehead*, Russel and Russel Publishers, ISBN 978-0-8462-0970-6
- Quine, W.v.O (1960), "Carnap and Logical Truth", *Synthese*, **12** (4): 350–374, doi:10.1007/BF00485423 (<https://doi.org/10.1007%2FBF00485423>)
- Mark A. Satterthwaite, "Strategy-proofness and Arrow's Conditions: Existence and Correspondence Theorems for Voting Procedures and Social Welfare Functions", *Journal of Economic Theory* 10 (April 1975), 187–217.
- Siegfried, Tom (2006), *A Beautiful Math*, Joseph Henry Press, ISBN 978-0-309-10192-9
- Skyrms, Brian (1990), *The Dynamics of Rational Deliberation*, Harvard University Press, ISBN 978-0-674-21885-7
- Skyrms, Brian (1996), *Evolution of the social contract*, Cambridge University Press, ISBN 978-0-521-55583-8
- Skyrms, Brian (2004), *The stag hunt and the evolution of social structure*, Cambridge University Press, ISBN 978-0-521-53392-8

- Sober, Elliott; Wilson, David Sloan (1998), *Unto others: the evolution and psychology of unselfish behavior*, Harvard University Press, ISBN 978-0-674-93047-6
- Thrall, Robert M.; Lucas, William F. (1963), "*n*-person games in partition function form", *Naval Research Logistics Quarterly*, **10** (4): 281–298, doi:10.1002/nav.3800100126 (<https://doi.org/10.1002%2Fnav.3800100126>)
- Dolev, Shlomi; Panagopoulou, Panagiota; Rabie, Mikael; Schiller, Elad Michael; Spirakis, Paul (2011), "Rationality authority for provable rational behavior" (<https://research.chalmers.se/en/publication/230780>), *Proceedings of the 30th annual ACM SIGACT-SIGOPS symposium on Principles of distributed computing*, pp. 289–290, doi:10.1145/1993806.1993858 (<https://doi.org/10.1145%2F1993806.1993858>), ISBN 9781450307192
- Chastain, E. (2014), "Algorithms, games, and evolution", *Proceedings of the National Academy of Sciences*, **111** (29): 10620–10623, Bibcode:2014PNAS..11110620C (<http://ui.adsabs.harvard.edu/abs/2014PNAS..11110620C>), doi:10.1073/pnas.1406556111 (<https://doi.org/10.1073%2Fpnas.1406556111>), PMC 4115542 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4115542>), PMID 24979793 (<https://www.ncbi.nlm.nih.gov/pubmed/24979793>)

External links

- James Miller (2015): Introductory Game Theory Videos (<https://www.youtube.com/playlist?list=PLqekkRyYeow3cR9U4c4wklek2pXxORPn>).
- Hazewinkel, Michiel, ed. (2001) [1994], "Games, theory of" (<https://www.encyclopediaofmath.org/index.php?title=p/g043280>), *Encyclopedia of Mathematics*, Springer Science+Business Media B.V. / Kluwer Academic Publishers, ISBN 978-1-55608-010-4
- Paul Walker: History of Game Theory Page (<https://web.archive.org/web/20000815223335/http://www.economics.harvard.edu/~aroeth/alroeth.html>).
- David Levine: Game Theory. Papers, Lecture Notes and much more stuff. (<http://dklevine.com/>)
- Alvin Roth:"Game Theory and Experimental Economics page" (<https://web.archive.org/web/20000815223335/http://www.economics.harvard.edu/~aroeth/alroeth.html>). Archived from the original (<http://www.economics.harvard.edu/~aroeth/alroeth.html>) on 15 August 2000. Retrieved 13 September 2003. — Comprehensive list of links to game theory information on the Web
- Adam Kalai: Game Theory and Computer Science (https://web.archive.org/web/20080416035356/http://wiki.cc.gatech.edu/theory/index.php/CS_8803_-_Game_Theory_and_Computer_Science_Spring_2008) — Lecture notes on Game Theory and Computer Science
- Mike Shor: GameTheory.net (<http://www.gametheory.net/>) — Lecture notes, interactive illustrations and other information.
- Jim Ratliff's Graduate Course in Game Theory (<http://virtualperfection.com/gametheory/>) (lecture notes).
- Don Ross: Review Of Game Theory (<http://plato.stanford.edu/entries/game-theory/>) in the *Stanford Encyclopedia of Philosophy*.
- Bruno Verbeek and Christopher Morris: Game Theory and Ethics (<http://plato.stanford.edu/entries/game-ethics/>)
- Elmer G. Wiens: Game Theory (<http://www.egwald.ca/operationsresearch/gameintroduction.php>) — Introduction, worked examples, play online two-person zero-sum games.
- Marek M. Kaminski: Game Theory and Politics (<http://webfiles.uci.edu/mkaminsk/www/courses.html>) — Syllabuses and lecture notes for game theory and political science.
- Websites on game theory and social interactions (<http://www.socialcapitalgateway.org/eng-gametheory.htm>)
- Kesten Green's Conflict Forecasting (<https://web.archive.org/web/20110411143752/http://conflictforecasting.com/>) at the Wayback Machine (archived 11 April 2011) — See Papers (<http://www.forecastingprinciples.com/paperpdf/Greenforecastinginconflict.pdf>) for evidence on the accuracy of forecasts from game theory and other methods (<http://www.decisionworkshops.com/#/graphs-of-findings/4553562008>).
- McKelvey, Richard D., McLennan, Andrew M., and Turocy, Theodore L. (2007) *Gambit: Software Tools for Game Theory* (<http://gambit.sourceforge.net/>).
- Benjamin Polak: Open Course on Game Theory at Yale (<http://oyc.yale.edu/economics/game-theory>) videos of the course (https://web.archive.org/web/20131101141402/http://www.youtube.com/view_play_list?p=6EF60E1027E1A10B)
- Benjamin Moritz, Bernhard Könsgen, Danny Bures, Ronni Wiersch, (2007) *Spieltheorie-Software.de: An application for Game Theory implemented in JAVA* (<https://web.archive.org/web/20130718133141/http://www.spieltheorie-software.de/>).
- Antonin Kucera: Stochastic Two-Player Games (<http://slideslive.com/38891162/stochastic-twooplayer-games>).
- Yu-Chi Ho: What is Mathematical Game Theory (<http://blog.sciencenet.cn/home.php?mod=space&uid=1565&do=blog&id=17894>); What is Mathematical Game Theory (#2) (<http://blog.sciencenet.cn/home.php?mod=space&uid=1565&do=blog&id=20337>); What is Mathematical Game Theory (#3) (<http://blog.sciencenet.cn/home.php?mod=space&uid=1565&do=blog&id=21210>); What is Mathematical Game Theory (#4)-Many person game theory (<http://blog.sciencenet.cn/home.php?mod=space&uid=1565&do=blog&id=21735>); What is Mathematical Game Theory ?(#5) – Finale, summing up, and my own view (<http://blog.sciencenet.cn/home.php?mod=space&uid=1565&do=blog&id=21891>)

This page was last edited on 11 October 2019, at 18:09 (UTC).

Text is available under the [Creative Commons Attribution-ShareAlike License](#); additional terms may apply. By using this site, you agree to the [Terms of Use](#) and [Privacy Policy](#). Wikipedia® is a registered trademark of the [Wikimedia Foundation, Inc.](#), a non-profit organization.