Economics 208, Behavioral Game Theory **Winter 2004**

Vincent P. Crawford, 858-534-3452, vcrawfor@weber.ucsd.edu

Organization: The course meets Winter Quarter, from 8:00-9:20 on Tuesdays and Thursdays in Economics 300, with the first meeting on Tuesday, January 6 (don't miss the Epiphany!). My office hours will be Wednesdays from 2:00-3:00 or by appointment. Those who just want to hear the lectures should enroll S/U; there will then be no formal requirements. Those who want a grade should enroll for one; their requirement will be either a research paper on a topic in the general area of the course or a three-hour final exam at a time to be arranged in exam week. The final exam is the default for those enrolled for a grade; those who wish to substitute a paper should discuss the topic and timing with me by the fifth week. The final exam will include a half-hour essay question, which is now posted on the course web page; this question is meant to help you think about how to use behavioral game theory to do economics, and its choices give you some freedom to make it about the kind of economics you are interested in. There is also an optional problem set on the course web page, which should be good practice for the final exam and may help you think about some of the issues we discuss in lectures. If you are a student who plans to attend the lectures, please enroll either S/U or for a grade (this will help the Department convince the administration that graduate electives are worth offering).

Abstract: Behavioral game theory is a blend of theory and empirical regularities whose goal is the kind of understanding of strategic behavior needed to analyze economic, political, and social interactions. This requires understanding the issues addressed by behavioral decision theory, plus some that are specific to multi-person settings: (i) preference interdependence (as in altruism, envy, reciprocity, or spite); and (ii) players' mental models of other players. Here I narrow the focus to (ii), taking behavior as (mostly) rational in the decision-theoretic sense and self-interested.

Game theory has described players' mental models of others in two very different ways, which coexist too peacefully in the literature. Traditional (noncooperative) game theory assumes players form correct (self-confirming) beliefs about each other's decisions, and so, if rational, play a Nash equilibrium immediately. In effect this assumes players have perfect mental models of others (including others' mental models of them). Adaptive learning models instead study repeated play of analogous games, making assumptions directly about players' decisions and how they adjust them in response to experience; these assumptions invoke simplified mental models of others. In such models direct observation of others' decisions in analogous games takes the place of mental models, and (in sufficiently stationary environments) players can learn to play an equilibrium.

The main difference between the two approaches is the assumed sophistication of players' mental models, or their *strategic sophistication*. People's responses to games in the laboratory, and presumably in the field, usually reveal some sophistication, but seldom enough to focus their beliefs as required for equilibrium the first time they play a game. Although they often learn to play an equilibrium, the learning process is usually history-dependent and its outcome can be influenced by players' initial responses and their learning rules, which are influenced by their sophistication. (For instance, sophistication is the main difference between the behavioral assumptions of the two most often studied classes of learning rules, reinforcement and beliefs-based models.)

One can imagine a theory of sophistication that completely determines it the way traditional game theory seeks to completely determine behavior, but it is unlikely that a useful theory can dispense entirely with empirical knowledge. Behavioral game theory combines theory and empirical (often experimental) evidence to identify the most useful parts of traditional and adaptive theories, representing sophistication and certain other aspects of strategic behavior by stable behavioral parameters, measuring them, and developing the implications of the resulting models.

The course will begin by reviewing the leading theories of players' initial responses to games (iterated reasoning about rationality or beliefs, backward and forward induction, and equilibrium-selection conventions based on structure, framing, and/or fairness) and using experimental evidence to explore how the factors they consider influence behavior. The course will then discuss theories of adaptive learning, using experimental evidence to explore the structure of learning rules and how learning interacts with initial responses to determine limiting outcomes.

Outline and Readings: The most important readings are marked * and those on reserve as hard copies are marked +. There is no formal text, but there are useful readings in:
Colin Camerer, *Behavioral Game Theory: Experiments on Strategic Interaction*, Princeton, 2003
Vincent Crawford, "Theory and Experiment in the Analysis of Strategic Interaction," Chapter 7 in David Kreps and Ken Wallis (eds.), *Advances in Economics and Econometrics: Theory and Applications, Seventh World Congress*, Vol. I, Cambridge 1997; reprinted with minor changes in Colin Camerer, George Loewenstein, and Matthew Rabin, editors, *Readings in Behavioral Economics*, Princeton and Russell Sage Foundation, February 2004
Douglas Davis and Charles Holt, *Experimental Economics*, Princeton, 1993
John Kagel and Alvin Roth, editors, *Handbook of Experimental Economics*, Princeton 1995

I have ordered some copies of Camerer for the bookstore. Earlier versions of most of the material in the book are posted at "Camerer": http://www.hss.caltech.edu/CourseSites/Psy101/psy101.html, but you may have to search for the right parts using the section heads from the published version. I also give links (sometimes from which to search) for other things available online: e.g JSTOR: http://www.jstor.org/jstor/, Kluwer: http://www.kluweronline.com/, and ScienceDirect: http://www.sciencedirect.com/science/journals/economics.

1. General background readings on game theory
*Camerer, Appendix 1.1 "Basic Game Theory" (pp. 25-34)
David Kreps, *Game Theory and Economic Modelling*, Oxford 1990
Thomas Schelling, *The Strategy of Conflict*, Oxford 1960 or Harvard 1980
Robert Gibbons, "An Introduction to Applicable Game Theory," *Journal of Economic Perspectives* 11 (1997), 127-149 (http://www.jstor.org/jstor/)

2. Overview of behavioral game theory and game experiments
*+Crawford, Sections 1-3 (pp. 206-216 in original) and Section 7 (pp. 235-236)
*Camerer, Chapter 1, "Introduction," and Appendix 1.2 "Experimental Design" (pp. 34-42)
*Colin Camerer, Teck-Hua Ho, and Juin-Kuan Chong, "Behavioral Game Theory: Thinking, Learning, and Teaching," 2001, (http://www.hss.caltech.edu/~camerer/Camerer.pdf; see also slides at http://www.iies.su.se/nobel/papers.htm)
Alvin Roth, Chapter 1, pp. 1-23 in Kagel and Roth

Alvin Roth, "Game Theory as a Part of Empirical Economics," *Economic Journal* 101 (1991), 107-114 (http://www.jstor.org/jstor/)

Jacob Goeree and Charles Holt, "Ten Little Treasures of Game Theory and Ten Intuitive Contradictions," *American Economic Review* 91 (2001), 1402-1422 (http://www.jstor.org/jstor/)

Reinhard Selten, "Features of Experimentally Observed Bounded Rationality," *European Economic Review* 42 (1998), 413-436 (http://www.sciencedirect.com/science/journals/economics)

3. Theory and evidence on initial responses to games (spaces separate groups of readings)

a. Iterated dominance and equilibrium in simultaneous-move games

*+Crawford, Section 4 (pp. 216-220)

*Camerer, Chapter 5, "Dominance-Solvable Games" (pp. 199-264)

Adam Brandenburger, "Knowledge and Equilibrium in Games," *Journal of Economic Perspectives* 6 (1992), 83-101 (http://www.jstor.org/jstor/)

+Matthew Rabin, "Incorporating Behavioral Assumptions into Game Theory," Chapter 4 (pp. 69-87) in James Friedman (ed.), *Problems of Coordination in Economic Activity*, Kluwer 1994

Richard McKelvey and Thomas Palfrey, "Quantal Response Equilibria for Normal-Form Games," *Games and Economic Behavior* 10 (1995), 6-38 (http://www.sciencedirect.com/science/journals/economics)

Philip Haile, Ali Hortacsu, and Grigory Kosenock, "On the Empirical Content of Quantal Response Equilibrium," Yale, 2003 (http://www.econ.yale.edu/~pah29/working.htm)

Erik Eyster and Matthew Rabin, "Cursed Equilibrium," 2000 (http://www.nuff.ox.ac.uk/Users/Eyster/papers/eurocurse.pdf)

Dale Stahl and Paul Wilson, "On Players' Models of Other Players: Theory and Experimental Evidence," *Games and Economic Behavior* 10 (1995), 218-254 (http://www.sciencedirect.com/science/journals/economics)

Miguel Costa-Gomes, Vincent Crawford, and Bruno Broseta, "Cognition and Behavior in Normal-Form Games: an Experimental Study," *Econometrica* 69 (2001), 1193-1235 (http://www.jstor.org/ or http://weber.ucsd.edu/~vcrawfor/PubPapers.html)

Rosemarie Nagel, "Unraveling in Guessing Games: An Experimental Study," *American Economic Review* 85 (1995), 1313-1326 (http://www.jstor.org/jstor/)

Teck-Hua Ho, Colin Camerer, and Keith Weigelt, "Iterated Dominance and Iterated Best Response in Experimental '*p*-Beauty Contests'," *American Economic Review* 88 (1998), 947-969 (http://www.jstor.org/jstor/)

Miguel Costa-Gomes and Vincent Crawford, "Cognition and Behavior in Two-Person Guessing Games: An Experimental Study," (paper, instructions, data, and slides at http://weber.ucsd.edu/~vcrawfor/#Guess)

b. Backward induction, subgame-perfectness, and forward induction in extensive-form games

*+Crawford, Sections 4.2 (pp. 218-220), 5.1 (pp. 220-221), and 6.3 (p.230)

*Camerer, Section 4.2 "Structured Bargaining" (pp. 161-182), Chapter 5, "Dominance-Solvable Games" (pp. 199-264), and Section 7.2 "Asymmetric Players: Battle of the Sexes" (pp. 353-367)

Robert Aumann, "Backward Induction and Common Knowledge of Rationality," *Games and Economic Behavior* 8 (1995), 6-19

(http://www.sciencedirect.com/science/journals/economics)
Richard McKelvey and Thomas Palfrey, "Quantal Response Equilibria for Extensive-Form Games," *Experimental Economics* 1 (1998), 9-41 (http://www.kluweronline.com/)
Elchanen Ben-Porath and Eddie Dekel, "Signaling Future Actions and the Potential for Sacrifice," *Journal of Economic Theory* 57 (1992), 36-51 (http://www.sciencedirect.com/science/journals/economics)

T. Randolph Beard and Richard Beil, "Do People Rely on the Self-interested Maximization of Others? An Experimental Test," *Management Science* 40 (1994), 252-262
Richard McKelvey and Thomas Palfrey, "An Experimental Study of the Centipede Game," *Econometrica* 60 (1992), 803-836 (http://www.jstor.org/jstor/)
Andrew Schotter, Keith Weigelt, and Charles Wilson, "A Laboratory Investigation of Multiperson Rationality and Presentation Effects," *Games and Economic Behavior* 6 (1994), 445-468 (http://www.sciencedirect.com/science/journals/economics)
David Cooper and John Van Huyck, "Evidence on the Equivalence of the Strategic and Extensive Form Representation of Games," *Journal of Economic Theory* 110 (2003), 290-308 (http://www.sciencedirect.com/science/journals/economics)

Alvin Roth, Vesna Prasnikar, Masahiro Okuno-Fujiwara, and Shmuel Zamir, "Bargaining and Market Behavior in Jerusalem, Ljubljana, Pittsburgh, and Tokyo: An Experimental Study," *American Economic Review* 81 (1991), 1068-1095 (http://www.jstor.org/jstor/)
Miguel Costa-Gomes and Klaus G. Zauner, "Ultimatum Bargaining Behavior in Israel, Japan, Slovenia, and the United States: A Social Utility Analysis," *Games and Economic Behavior* 34 (2001), 238-269 (http://www.sciencedirect.com/science/journals/economics)

Vincent Crawford, "Introduction to Experimental Game Theory," *Journal of Economic Theory* 104 (2002), 1-15 (pp. 3-6 introduce next two papers) (http://www.sciencedirect.com/science/journals/economics)
Eric Johnson, Colin Camerer, Sankar Sen, and Talia Rymon (2002): "Detecting Failures of Backward Induction: Monitoring Information Search in Sequential Bargaining," *Journal of Economic Theory*, 104, 16-47 (http://www.sciencedirect.com/science/journals/economics)
Ken Binmore, John McCarthy, Giovanni Ponti, Larry Samuelson, and Avner Shaked, "A Backward Induction Experiment," *Journal of Economic Theory*, 104 (2002), 48-88 (http://www.sciencedirect.com/science/journals/economics)

Vincent Crawford, "A Survey of Experiments on Communication via Cheap Talk," *Journal of Economic Theory* 78 (1998), 286-298 (http://www.sciencedirect.com/science/journals/economics)
Russell Cooper, Douglas DeJong, Robert Forsythe, and Thomas Ross, "Alternative Institutions for Resolving Coordination Problems: Experimental Evidence on Forward Induction and Preplay Communication," pp. 129-146 in James Friedman (ed.), *Problems of Coordination in Economic Activity*, Boston : Kluwer, 1994
Colin Camerer and Eric Johnson, "Thinking About Attention in Games: Backward and Forward Induction," 2003 (http://www.hss.caltech.edu/~camerer/ericchap5.pdf)

c. Selection among multiple strict equilibria via structure, framing, or complexity

*Camerer, Chapter 7 "Coordination" (pp. 336-407)

*+Crawford, Sections 5.1 and 5.2 (pp. 220-223)

John Harsanyi and Reinhard Selten, *A General Theory of Equilibrium Selection in Games*, MIT 1988

Russell Cooper, Douglas DeJong, Robert Forsythe, and Thomas Ross, "Selection Criteria in Coordination Games: Some Experimental Results," *American Economic Review* 80 (1990), 218-233 (http://www.jstor.org/jstor/)

Vincent Crawford "Adaptive Dynamics in Coordination Games," *Econometrica* 63 (January 1995), 103-143, Section 2 (pp. 106-109, especially footnote 8) (http://www.jstor.org/jstor/ or http://weber.ucsd.edu/~vcrawfor/PubPapers.html)

Colin Camerer, Teck-Hua Ho, and Juin-Kuan Chong, "A Cognitive Hierarchy Theory of One-Shot Games and Experimental Analysis," 2003 (http://www.hss.caltech.edu/~camerer/QJErev8.pdf)

+Teck Hua Ho and Keith Weigelt, "Task Complexity, Equilibrium Selection, and Learning: An Experimental Study," *Management Science* 42 (1996), 659-679

Judith Mehta, Chris Starmer, and Robert Sugden, "The Nature of Salience: An Experimental Investigation of Pure Coordination Games," *American Economic Review* 84 (1994), 658-674 (http://www.jstor.org/jstor/)

d. Selection among multiple strict equilibria via fairness and/or precedent

*+Crawford, Section 5.3 (pp. 223-227)

*Camerer, Section 4.1 "Unstructured Bargaining" (pp. 153-161)

Schelling, Chapter 3, "Bargaining, Communication, and Limited War," and Appendix C

Lones Smith and Ennio Stachetti, "Aspirational Bargaining," manuscript, 2002 (http://www-personal.umich.edu/~lones/ftp/aspire.pdf)

Alvin Roth and Francoise Schoumaker, "Expectations and Reputations in Bargaining: An Experimental Study," *American Economic Review* (1983), 362-372 (http://www.jstor.org/jstor/)

+Alvin Roth, "Bargaining Phenomena and Bargaining Theory," Chapter 2 (pp. 14-41) in Roth (ed.), *Laboratory Experimentation in Economics: Six Points of View*, Cambridge, 1987

+Alvin Roth, "Toward a Focal-Point Theory of Bargaining," Chapter 12 (pp. 259-268) in Roth, (ed.), *Game-Theoretic Models of Bargaining*, Cambridge, 1985

Diego Moreno and John Wooders, "An Experimental Study of Communication and Coordination in Noncooperative Games, *Games and Economic Behavior* 24 (1998), 47-76 (http://www.sciencedirect.com/science/journals/economics)

2. Theory and evidence on adaptive learning

a. Overview of adaptive learning models

*+Crawford, Sections 2.3 and 2.4 (pp. 211-214) and Section 6 (pp. 227-235)

*Camerer, Chapter 3, "Mixed-Strategy Equilibrium Games" (pp. 118-150) and Chapter 6, "Learning" (pp. 265-335 in book; earlier version is not online)

Colin Camerer and Teck-Hua Ho, "Experience-weighted Attraction Learning in Normal Form Games," *Econometrica* 67 (1999), 827-874 (http://www.jstor.org/jstor/)

Yin-Wong Cheung and Daniel Friedman, "Individual Learning in Normal-Form Games: Some Experimental Results," *Games and Economic Behavior* 19 (1997), 46-76 (http://www.sciencedirect.com/science/journals/economics)

Ido Erev and Alvin E. Roth, "Predicting how people play games: Reinforcement Learning in Experimental Games with Unique, Mixed Strategy Equilibria," *American Economic Review* 88 (1998), 848-881 (http://www.jstor.org/jstor/)

Jason M. Shachat, "Mixed Strategy Play and the Minimax Hypothesis," *Journal of Economic Theory*, 104 (2002), 189-226 (http://www.sciencedirect.com/science/journals/economics)

b. Equilibrium selection via learning

*+Crawford, Section 6 (pp. 227-235)

*Camerer, Sections 7.4 "Payoff-Asymmetric Order-Statistic Games" (pp. 375-395) and 7.6 "Applications: Path-Dependence, Market Adoption, and Corporate Culture" (pp. 399-405), 8.1 "Simple Signaling Games and Adaptive Dynamics" (pp. 408-427), and 8.4 "Conclusion" (pp. 462-464)

Jordi Brandts and Charles Holt, "An Experimental Test of Equilibrium Dominance in Signaling Games," *American Economic Review* 82 (1992), 1350-1365 (http://www.jstor.org/jstor/)

Jeffrey Banks, Colin Camerer, and David Porter, "An Experimental Analysis of Nash Refinements in Signaling Games," *Games and Economic Behavior* 6 (1994), 1-31 (http://www.sciencedirect.com/science/journals/economics)

David Harless and Colin Camerer, "An Error Rate Analysis of Experimental Data Testing Nash Refinements," *European Economic Review* 39 (1995), 649-660 (http://www.sciencedirect.com/science/journals/economics)

John Van Huyck, Joseph Cook, and Raymond Battalio (1997): "Adaptive Behavior and Coordination Failure," *Journal of Economic Behavior and Organization* 32, 483-503 (http://www.sciencedirect.com/science/journals/economics)

John Van Huyck, Raymond Battalio, and Frederick Rankin, "On the Origin of Convention: Evidence from Coordination Games," *Economic Journal* 107 (1997), 576-597 (http://www.jstor.org/jstor/)

Vincent Crawford, "Learning Dynamics, Lock-in, and Equilibrium Selection in Experimental Coordination Games," in Ugo Pagano and Antonio Nicita, editors, *The Evolution of Economic Diversity*, London and New York: Routledge, 2001, 133-163; UCSD Discussion Paper 97-19 (http://weber.ucsd.edu/~vcrawfor/ucsd9719.pdf or ftp://weber.ucsd.edu/pub/econlib/dpapers/ucsd9719.pdf)

Vincent Crawford "Adaptive Dynamics in Coordination Games," *Econometrica* 63 (January 1995), 103-143 (http://weber.ucsd.edu/~vcrawfor/PubPapers.html or http://www.jstor.org/jstor/)

Colin Camerer and Teck-Hua Ho, "Experience-weighted Attraction Learning in Coordination Games" Probability Rules, Heterogeneity, and Time Variation," *Journal of Mathematical Psychology* 42 (1998), 305-326 (http://www.sciencedirect.com/science/journal/00222496)

John Van Huyck, Raymond Battalio, and Richard Beil, "Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure," *American Economic Review* 80 (1990), 234-248 (http://www.jstor.org/jstor/)

John Van Huyck, Raymond Battalio, and Richard Beil, "Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games," *Quarterly Journal of Economics* 106 (1991), 885-910 (http://www.jstor.org/jstor/)

Vincent Crawford and Bruno Broseta, "What Price Coordination? The Efficiency-enhancing Effect of Auctioning the Right to Play," *American Economic Review* 88 (March 1998), 198-225 (http://www.jstor.org/jstor/)

John Van Huyck, Raymond Battalio, and Richard Beil, "Asset Markets as an Equilibrium Selection Mechanism: Coordination Failure, Game Form Auctions, and Tacit Communication," *Games and Economic Behavior* 5 (1993), 485-504 (http://www.sciencedirect.com/science/journals/economics)

c. Rule learning and strategic teaching

*Camerer, Section 6.7 "Rule Learning" (pp. 324-331)

Dale Stahl, "Boundedly Rational Rule Learning in a Guessing Game," *Games and Economic Behavior* 16 (1996), 303-330 (http://www.sciencedirect.com/science/journals/economics)

Teck-Hua Ho, Colin Camerer, and Keith Weigelt, "Iterated Dominance and Iterated Best Response in Experimental 'P-Beauty Contests'," *American Economic Review* 88 (1998), 947-969

Vincent Crawford, "Introduction to Experimental Game Theory," *Journal of Economic Theory*, 104 (2002), 1-15 (pp. 8-10 introduce next paper) (http://www.sciencedirect.com/science/journals/economics)

Colin Camerer, Teck-Hua Ho, and Juin-Kuan Chong, "Sophisticated Experience-Weighted Attraction Learning and Strategic Teaching in Repeated Games," *Journal of Economic Theory*, 104 (2002), 137-188 (http://www.sciencedirect.com/science/journals/economics)

d. Learning from imperfect analogies

*Vincent Crawford, "Introduction to Experimental Game Theory," *Journal of Economic Theory*, 104 (2002), 1-15 (pp. 11-12 introduce next two papers) (http://www.sciencedirect.com/science/journals/economics)

John Van Huyck and Raymond Battalio, "Prudence, Justice, Benevolence, and Sex: Evidence from Similar Bargaining Games," *Journal of Economic Theory*, 104 (2002), 227-246 (http://www.sciencedirect.com/science/journals/economics)

Ray Battalio, F. Rankin, and John Van Huyck, "Strategic Similarity and Emergent Conventions Evidence from Similar Stag Hunt Games," *Games and Economic Behavior*, 32 (2000), 315-337 (http://www.sciencedirect.com/science/journals/economics)

David Cooper and John Kagel, "Learning and Transfer in Signaling Games," manuscript, 2002 (not online; pdf sent by request)

Larry Samuelson, "Analogies, Adaptation, and Anomalies," *Journal of Economic Theory*, 97 (2001), 320-366 (http://www.sciencedirect.com/science/journals/economics)

Philippe Jehiel, "Analogy-Based Expectation Equilibrium," manuscript, 2003 (http://www.enpc.fr/ceras/jehiel/analrev.pdf)