Economics 209A, Theory and Application of Non-cooperative Games, Part II
Vincent P. Crawford, 858-534-3452, vcrawfor@weber.ucsd.edu, UC Berkeley, Spring 2003

Organization: Part II of Economics 209A will meet from 10:00-11:50 in 639 Evans and then from 12:00-1:00 in 47 Evans (just like Part I), on the four Mondays: March 3, 10, 17, and 31. My office hours on those days will be from 2:45-3:45 or by appointment in a location to be announced. The only requirements are a problem set posted on the course web page, linked on my home page at http://weber.ucsd.edu/~vcrawfor/, to be done independently and due at the start of class March 31 (the answers will be posted on April 1); and a final exam on Monday, April 7, from 10:00-11:50 in 639 Evans. The problem set will count as 35% of your grade, and the exam will count 65%. Your grade on Part II will be combined with your grade from Part I, taught by Joel Sobel, to determine your course grade. The final exam includes a half-hour essay question, which is meant to get you thinking about how to use behavioral game theory to do economics; a choice gives you some freedom to make the question about the kind of economics you are interested in. *This essay question is* now *posted on the course web page; procrastinators and preproperators alike are strongly encouraged to start thinking about it before April 7.*

Abstract: The topic is behavioral game theory, 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 preferences as rational in the decision-theoretic sense and (mostly) 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: backward induction, iterated reasoning about rationality or beliefs, and conventions based on structure, fairness, or framing; and using experimental evidence to explore how these factors influence initial responses. The course will conclude by discussing alternative theories of adaptive learning; and using experimental evidence to explore the nature of learning and how it interacts with initial responses to determine limiting outcomes. (A subsection headed "Learning from imperfect analogies" examines what it means for an environment to be "sufficiently stationary.")

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 several 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; to be reprinted with minor changes in Colin Camerer, George Loewenstein, and Matthew Rabin, editors, *Readings in Behavioral Economics*, New York: Russell Sage Foundation, 2003
Thomas Schelling, *The Strategy of Conflict*, Harvard 1980

I have ordered copies of Camerer (published 21 February 2003) and Schelling for the bookstore.

Links to things that are available online (some to publisher home pages, from which you can search):

Camerer: http://www.hss.caltech.edu/CourseSites/Psy101/psy101.html
Kluwer: http://www.kluweronline.com/
Elsevier: http://www.elsevier.com/homepage/sae/econworld/econbase/eer/frame.htm
ScienceDirect: http://www.sciencedirect.com/science
JSTOR: http://www.jstor.org

1. Introduction to Behavioral Game Theory and Game Experiments
*Camerer, Chapter 1, "Introduction," and Appendices 1-2 (Camerer)
*+Crawford, Sections 1-3 (pp. 206-216 in original) and Section 7 (pp. 235-236)
*Schelling, Chapter 6, "Game Theory and Experimental Research"
Colin Camerer and Teck-Hua Ho, and Juin-Kuan Chong, "Behavioral Game Theory: Thinking, Learning, and Teaching," manuscript **(**http://www.hss.caltech.edu/~camerer/Camerer.pdf)
Jacob Goeree and Charles Holt, "Ten Little Treasures of Game Theory and Ten Intuitive Contradictions," *American Economic Review* 91 (2001), 1402-1422 (not available online)
Alvin Roth, Chapter 1, pp. 1-23 in John Kagel and Alvin Roth (eds.), *Handbook of Experimental Economics*, Princeton 1995
Reinhard Selten, "Features of Experimentally Observed Bounded Rationality," *European Economic Review* 42 (1998), 413-436 (Elsevier)
*Adam Brandenburger, "Knowledge and Equilibrium in Games," *Journal of Economic Perspectives* 6 (1992), 83-101 (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 (ScienceDirect)
Richard McKelvey and Thomas Palfrey, "Quantal Response Equilibria for Extensive-Form Games," *Experimental Economics* 1 (1998), 9-41 (Kluwer)

2. Evidence on Initial Responses to Games
a. Backward induction and subgame-perfectness in extensive-form games
*Camerer, Chapter 4, "Bargaining," Sections 3.1-3.3 (pp. 12-28) (Camerer)
*+Crawford, Sections 5.1 (pp. 220-221) and 6.3 (p.230)
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
Andrew Schotter, Keith Weigelt, and Charles Wilson, "A Laboratory Investigation of Multiperson Rationality and Presentation Effects," *Games and Economic Behavior* 6 (1994), 445-468 (ScienceDirect)
David Cooper and John Van Huyck, "Evidence on the Equivalence of the Strategic and Extensive Form Representation of Games," *Journal of Economic Theory* (2003), in press (http://econlab10.tamu.edu/JVH_gtee/Sim1.pdf or http://eexcl.ucsd.edu/CooperVH02.pdf)
Vincent Crawford, "Introduction to Experimental Game Theory," *Journal of Economic Theory*, 104 (2002), 1-15 (pp. 3-6 introduce next two papers) (ScienceDirect)
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 (ScienceDirect)
Ken Binmore, John McCarthy, Giovanni Ponti, Larry Samuelson, and Avner Shaked, "A Backward Induction Experiment," *Journal of Economic Theory*, 104 (2002), 48-88 (ScienceDirect)
Robert Aumann, "Backward Induction and Common Knowledge of Rationality," *Games and Economic Behavior* 8 (1995), 6-19 (ScienceDirect)
Richard McKelvey and Thomas Palfrey, "An Experimental Study of the Centipede Game," *Econometrica* 60 (1992), 803-836 (JSTOR)
b. Iterated dominance and equilibrium in simultaneous-move games
*Camerer, Chapter 5, "Iterated Reasoning in Dominance-Solvable games," especially Sections 1-4.2 (pp. 0-30) and Sections 6-7 (pp. 54-80) (Camerer)
Dale Stahl and Paul Wilson, "On Players' Models of Other Players: Theory and Experimental Evidence," *Games and Economic Behavior* 10, (1995), 218-254 (ScienceDirect)
Miguel Costa-Gomes, Vincent Crawford, and Bruno Broseta, "Cognition and Behavior in Normal-Form Games: an Experimental Study," *Econometrica* 69 (2001), 1193-1235 (http://weber.ucsd.edu/~vcrawfor/PubPapers.html)
Rosemarie Nagel, "Unraveling in Guessing Games: An Experimental Study," *American Economic Review* 85 (1995), 1313-1326 (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 (JSTOR)
Miguel Costa-Gomes and Vincent Crawford, "Cognition and Behavior in Two-Person Guessing Games: An Experimental Study," (http://eexcl.ucsd.edu/22JulyGuessingMain.pdf and http://eexcl.ucsd.edu/GuessingDataSlides.pdf)

c. Equilibrium selection via structure

*Camerer, Chapter 7, “Coordination,” Sections 3.1-3.3, pp. 27-40, and Section 4, pp. 47-73, and Chapter 8, “Signaling and Reputation,” Section 1, pp. 0-11 (Camerer)

*Schelling, Appendix C, “For the Abandonment of Symmetry in Game Theory”

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

Russell Cooper, Douglas DeJong, Robert Forsythe, and Thomas Ross, "Alternative Institutions for Resolving Coordination Problems: Experimental Evidence on Forward Induction and Preplay Communication," Chapter 7 (pp. 129-146) in James Friedman (ed.), *Problems of Coordination in Economic Activity*, Kluwer 1994

Elchanen Ben-Porath and Eddie Dekel, "Signaling Future Actions and the Potential for Sacrifice," Journal of Economic Theory 57 (1992), 36-51 (ScienceDirect)

*Vincent Crawford "Adaptive Dynamics in Coordination Games," *Econometrica* 63 (January 1995), 103-143, Section 2 (pp. 106-109, especially footnote 8) (JSTOR)

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

*+Teck Hua Ho and Keith Weigelt, "Task Complexity, Equilibrium Selection, and Learning: An Experimental Study," *Management Science* 42 (1996), 659-679 (not online)

d. Equilibrium selection via fairness (and the strategic use of arguments based on fairness)

*Camerer, Chapter 4, “Bargaining,” Sections 1-2 (pp. 1-8) (Camerer)

*Schelling, Chapter 3, “Bargaining, Communication, and Limited War,” and Appendix C

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

+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

Alvin Roth and Francoise Schoumaker, "Expectations and Reputations in Bargaining: An Experimental Study," *American Economic Review* (1983), 362-372 (JSTOR)

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

e. Equilibrium selection via framing

*Camerer, Chapter 7, “Coordination,” Sections 1 and 2, pp. 0-27, and Sections 3.4 and 3.5, pp. 40-47 for this part (Camerer)

*+Crawford, Section 5.2 (pp. 222-223)

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 (JSTOR)

2. Evidence on Learning

a. Overview of "evolutionary" and adaptive learning models

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

*Camerer, Chapter 6, "Learning" (not online)

Colin Camerer and Teck-Hua Ho, "Experience-weighted Attraction Learning in Normal Form Games," *Econometrica* 67 (1999), 827-874 (JSTOR)

Paul Milgrom and John Roberts, "Adaptive and Sophisticated Learning in Normal Form Games," *Games and Economic Behavior* 3 (1991), 82-100 (not online)

b. Refinements, equilibrium selection, and coordination

*Camerer, Chapter 7, "Coordination" and Chapter 8, "Signaling and Reputation," Section 2.1, pp. 11-18 (Camerer)

Van Huyck, John, Joseph Cook, and Raymond Battalio (1997): "Adaptive Behavior and Coordination Failure," *Journal of Economic Behavior and Organization* 32, 483-503 (ScienceDirect)

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

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

John Van Huyck, Raymond Battalio, and Richard Beil, "Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure," *American Economic Review* 80 (1990), 234-248 (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 (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 (ScienceDirect)

Jordi Brandts, and Charles Holt, "An Experimental Test of Equilibrium Dominance in Signaling Games," *American Economic Review* 82 (1992), 1350-1365 (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 (ScienceDirect)

c. Rule learning and strategic teaching

*Camerer, Chapter 8, “Signaling and Reputation,” Section 4.3, pp. 57-59 (Camerer)

Vincent Crawford, “Introduction to Experimental Game Theory,” *Journal of Economic Theory*, 104 (2002), 1-15 (pp. 8-10 introduce next paper) (ScienceDirect)

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 (ScienceDirect)

Dale Stahl, "Boundedly Rational Rule Learning in a Guessing Game," *Games and Economic Behavior* 16 (1996), 303-330 (ScienceDirect)

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 paper) (ScienceDirect)

John Van Huyck and Raymond Battalio, "Prudence, Justice, Benevolence, and Sex: Evidence from Similar Bargaining Games," *Journal of Economic Theory*, 104 (2002), 227-246 (ScienceDirect)

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 (ScienceDirect)

David Cooper and John Kagel, "Learning and Transfer in Signaling Games," manuscript, 2002 (not online)

Philippe Jehiel, “Analogy-Based Expectation Equilibrium,” manuscript, 2002 (http://www.enpc.fr/ceras/jehiel/analrev.pdf)

e. Mixed-strategy equilibrium (time permitting, which is unlikely)

*Camerer, Chapter 2, "Mixed-Strategy Equilibrium Games" (Camerer)

Yin-Wong Cheung and Daniel Friedman, "Individual Learning in Normal-Form Games: Some Experimental Results," *Games and Economic Behavior* 19 (1997), 46-76 (ScienceDirect)

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 (JSTOR)

*Vincent Crawford, “Introduction to Experimental Game Theory,” *Journal of Economic Theory*, 104 (2002), 1-15 (pp. 10-11 introduce next paper) (ScienceDirect)

Jason M. Shachat, "Mixed Strategy Play and the Minimax Hypothesis," *Journal of Economic Theory*, 104 (2002), 189-226 (ScienceDirect)