Segment on Behavioral Game Theory   Vincent Crawford, 534-3452, vcrawfor@dss.ucsd.edu
Economics 208, Games and Information (with Navin Kartik and David Miller)   Fall 2006

Organization: Economics 208 meets throughout Fall Quarter, from 8:00-9:20 on Mondays and Wednesdays in Economics 300. The seven lectures in my segment will be on November 8, 13, 15, 20, 22, 27, and 29. My office hours throughout the quarter will be Wednesdays from 2:00-3:00 or by appointment. The course segment website is linked at http://dss.ucsd.edu/~vcrawfor/#Courses.

Instead of a final exam, each segment will have its own take-home mini-exam/long problem set. You are expected to work on these individually, i.e. without consulting any classmates, faculty (except us), etc. My mini-exam will be posted on the course website by the end of class on November 29 and due by 4 p.m. Friday, December 1. This date is firm, except in case of severe, unforeseeable events, in which case exceptions must be requested as soon as possible, and before the deadline. The exam will include a flexible essay question, which is given at the end of this syllabus. This question is meant to help you think about how to use behavioral game theory to do economics; its choices give you some freedom to make it about the kind of economics you are interested in. An optional problem set, which should be good practice for the final exam and may help you think about some of the issues we discuss in lectures, will also be posted by November 8.

Introduction: Behavioral game theory is a blend of traditional game theory and empirical knowledge whose goal is the understanding of strategic behavior needed for applications. Such understanding includes topics from behavioral decision theory plus two topics that are specific to multi-person settings: (1) preference interdependence (such as altruism, envy, spite, or reciprocity); and (2) players' models of other players. Here I narrow the focus to (2), assuming that behavior is (mostly) rational in the decision-theoretic sense and self-interested. I further subdivide (2) into: (2a) how players model others' decisions in initial responses to games with no clear precedents; and (2b) how players learn to predict others' decisions in repeated play of analogous games.

Traditional game theory has approached questions (2a) and (2b) in very different ways. Initial responses are assumed to be determined by players thinking about the game and forming self-confirming beliefs about each other's decisions, which (if they are rational) lead them to equilibrium immediately. Learning is modeled by assuming that players adjust their beliefs in repeated play of analogous games in sensible, "adaptive" (but non-equilibrium) ways, which normally make them converge to an equilibrium eventually. Thus traditional models of initial responses assume that players have perfect mental models of others, while traditional models of learning assume that players have simplified models, which substitute direct observation of others' past decisions for the strategic reasoning that underlies equilibrium models of initial responses.

Behavioral game theory adapts these approaches in three ways, corresponding to (1), (2a), and (2b) above. (2a) starts from the observation that in games of any complexity, initial responses in the lab, and presumably in the field, are normally "strategic" in that they reflect attempts to use others' incentives to predict their decisions, but they often deviate systematically from equilibrium. This raises the question, "If people are strategic but don't always play an equilibrium, what do they do?" Answering this question is essential in applications involving games without clear precedents. (When the stock market re-opens after 9/11, do you sell airline stocks—or buy them on the theory that others will be too eager to sell? How will Bill Gates react when your start-up enters one of

"his" markets? Where on the coast of France do you land on D-Day?) The answer is also important in games with cloudy precedents, though the question of how players react to imperfect analogies is still on the research frontier. Finally, the answer is important in analyzing the comparative statics of changing a game's rules or payoffs; and in mechanism design, which involves creating new games that may have to "work" the first time (as in the FCC spectrum auctions).

(2b) seeks to identify the structure of players' learning rules. That structure determines whether, and how quickly, players will converge to equilibrium in a stationary environment, and how they will adjust to changes in the environment. It also has more subtle implications. If a typical application gives players ample opportunity to learn from others' previous decisions in analogous games, but the games have multiple equilibria, then learning is history-dependent and its limiting outcome is influenced by both the structure of players' learning rules and their initial responses.

As suggested above, behavioral game theory is inherently partly empirical. Because the kind of observability and controllability needed to test theories of strategic behavior is found only rarely in the field, most of the evidence comes from experiments. (The extent to which lab results "transfer" to analogous field environments is now a hot topic in experimental economics, but it will not be discussed here.) My approach in both (2a) and (2b) will be first to review existing evidence and use it to identify the most useful parts of traditional theories and measure behavioral parameters the theory does not reliably determine; and then (at least for (2a) to illustrate the use of the resulting models to resolve empirical puzzles by "re-doing" certain parts of strategic microeconomics.

The course will begin by reviewing the leading theories of 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 evidence to explore how the factors they consider influence behavior. The course will then discuss the leading theories of adaptive learning, using evidence to explore the structure of learning rules and how learning interacts with initial responses to determine limiting outcomes.

We will cover topics in the order in which they are listed, but there are many more topics and readings than we can possibly cover in seven lectures. (I have tried to be fairly comprehensive for those of you who want to study behavioral game theory in more depth.)

I don't list topics week by week because the rate of progress is hard to predict.

Outline and Readings: The most important readings are marked *. Several are from:

("CC") Colin Camerer, *Behavioral Game Theory: Experiments on Strategic Interaction*, Princeton, 2003
("VC") 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; linked in manuscript at http://dss.ucsd.edu/~vcrawfor/ShortTh&Exp.pdf.
("KR") John Kagel and Alvin Roth, editors, *Handbook of Experimental Economics,* Princeton 1995

1. Overview of behavioral game theory and game experiments

*CC, Chapter 1, "Introduction"; Appendix 1.1, "Basic Game Theory"; and Appendix 1.2, "Experimental Design"
*VC, Sections 1, "Introduction"; 2, "Theoretical Frameworks and Unresolved Questions"; 3, "Experimental Designs"; and 7, "Conclusion"

Useful background readings include (spaces separate topics):

Thomas Schelling, *The Strategy of Conflict,* Oxford 1960 or Harvard 1980

KR, Chapter 1, "Introduction to Experimental Economics" by Alvin Roth
Alvin Roth, "Game Theory as a Part of Empirical Economics," *Economic Journal* 101 (1991), 107-114 (http://www.jstor.org/jstor/)

2a. Theory and evidence on initial responses to games

i. Iterated dominance and equilibrium in simultaneous-move games

*CC, Chapter 5, "Dominance-Solvable Games"
*VC, Section 4, "Dominance and Iterated Dominance"
*Miguel Costa-Gomes and Vincent Crawford, "Cognition and Behavior in Two-Person Guessing Games: An Experimental Study," *American Economic Review* 96 (December 2006), in press; paper, instructions, data, and slides at http://dss.ucsd.edu/~vcrawfor/#Guess.

Useful background readings include (spaces separate topics):

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

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, 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://dss.ucsd.edu/~vcrawfor/CGCrBr01EMT.pdf).
Costa-Gomes, Miguel and Weizsäcker, Georg. "Stated Beliefs and Play in Normal-Form Games," 2005; linked at http://personal.lse.ac.uk/weizsack/Costa-Gomes_Weizsacker-27-04-06.pdf.

Example applications (spaces separate topics):

Camerer, Colin, Ho, Teck-Hua and Chong, Juin Kuan, "A Cognitive Hierarchy Model of Games,"
Quarterly Journal of Economics 119 (2004), 861-898
http://www.mitpressjournals.org/loi/qjec?cookieSet=1

Vincent Crawford, "Lying for Strategic Advantage: Rational and Boundedly Rational
Misrepresentation of Intentions," *American Economic Review* 93 (2003), 133-149.
(http://www.jstor.org/jstor/)

Vincent Crawford and Nagore Iriberri, "Fatal Attraction: Focality, Naivete, and Sophistication in
Experimental Hide-and-Seek Games," 2005; linked at http://dss.ucsd.edu/~vcrawfor/#Hide

On the last two papers, see also lecture slides on "Outguessing and Deception in Novel Strategic
Situations" at http://dss.ucsd.edu/~vcrawfor/SMUPubLecSlides.pdf or (slightly different)
http://dss.ucsd.edu/~vcrawfor/KelloggMEDSDeceptionSlides.pdf

Vincent Crawford and Nagore Iriberri, "Level-k Auctions: Can a Non-Equilibrium Model of
Strategic Thinking Explain the Winner's Curse and Overbidding in Private-Value
Auctions?," 2006; linked at http://dss.ucsd.edu/~vcrawfor/#Auctions.

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

*CC, Section 4.2, "Structured Bargaining"; Chapter 5, "Dominance-Solvable Games"; and Section
7.2, "Asymmetric Players: Battle of the Sexes"
*VC, Sections 4.2, "Ultimatum and alternating-offers bargaining"; 5.1, "Signaling games"; and 6.3,
"Simultaneous coordination revisited"

Useful background readings include (spaces separate topics):

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/)

Richard McKelvey and Thomas Palfrey, "Quantal Response Equilibria for Extensive-Form
Games," *Experimental Economics* 1 (1998), 9-41
(http://www.springerlink.com/content/1573-6938/)

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/journal/08998256)

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/journal/00220531)

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/journal/00220531)

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/journal/00220531)

Vincent Crawford, "A Survey of Experiments on Communication via Cheap Talk," *Journal of Economic Theory* 78 (1998), 286-298 (http://www.sciencedirect.com/science/journal/00220531)

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," in Isabel Brocas and Juan Carrillo (editors), The Psychology of Economic Decisions, Volume Two: Reasons and Choices, Oxford, 2004; linked in manuscript at (http://www.hss.caltech.edu/~camerer/ericchap5.pdf)

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

*CC, Section 4.1, "Unstructured Bargaining"; Chapter 7, "Coordination"
*VC, Section 5, "Simultaneous Coordination"
John Harsanyi and Reinhard Selten, *A General Theory of Equilibrium Selection in Games*, MIT 1988

Useful background readings include (spaces separate topics):

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://dss.ucsd.edu/~vcrawfor/Crawford95EMT.pdf)

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

Thomas Schelling, *The Strategy of Conflict,* Chapter 3, "Bargaining, Communication, and Limited War"; Appendix C

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/)

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

2b. Theory and evidence on adaptive learning

i. Overview of adaptive learning models

*CC, Chapter 3, "Mixed-Strategy Equilibrium Games"; Chapter 6, "Learning"
*VC, Sections 2.3, "Evolutionary game theory"; 2.4, "Adaptive learning models"; 6, "Dynamic Evidence"
*Colin Camerer and Teck-Hua Ho, "Experience-weighted Attraction Learning in Normal Form Games," *Econometrica* 67 (1999), 827-874 (http://www.jstor.org/jstor/)

Useful background readings include (spaces separate topics):

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/)

ii. Equilibrium selection via learning

*VC, Section 6, "Dynamic Evidence"
*CC, Sections 7.4, "Payoff-Asymmetric Order-Statistic Games"; 7.6, "Applications: Path-Dependence, Market Adoption, and Corporate Culture"; 8.1, "Simple Signaling Games and Adaptive Dynamics"; 8.4, "Conclusion"
*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://dss.ucsd.edu/~vcrawfor/ucsd9719.pdf)

Useful background readings include (spaces separate topics):

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/journal/08998256)

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/journal/00142921)

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/journal/01672681)

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 "Adaptive Dynamics in Coordination Games," *Econometrica* 63 (January 1995), 103-143 (http://www.jstor.org/jstor/ or http://dss.ucsd.edu/~vcrawfor/Crawford95EMT.pdf)

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/)

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)

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/journal/08998256)

iii. Rule learning and strategic teaching (not covered in lectures)
*CC, Section 6.7, "Rule Learning"

Useful background readings include:

Dale Stahl, "Boundedly Rational Rule Learning in a Guessing Game," *Games and Economic Behavior* 16 (1996), 303-330 (http://www.sciencedirect.com/science/journal/08998256)

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/)

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/journal/00220531)

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/journal/00220531)

iv. Learning from imperfect analogies (not covered in lectures)

Useful background readings include (spaces separate topics):

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/journal/00220531)

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/journal/00220531)

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/journal/08998256)

David Cooper and John Kagel, "Learning and Transfer in Signaling Games," 2004, linked at http://www.econ.ohio-state.edu/kagel/JEEA1.pdf

(The essay question for the mini-exam is on the next page.)

Economics 208, Essay question for the mini-exam   **Fall 2006**

This essay question will be part of the mini-exam. It is meant to get you thinking about how to use behavioral game theory to do economics; the choice gives you some freedom to make the question about the kind of economics you are interested in. My references should be easy to find.

Write a brief (one-page or less) essay on how research on the parts of behavioral game theory studied in this segment should change how we think about your choice of one of the following kinds of application. For some or perhaps all of them, more than one answer is defensible. Full credit will be given for any answer that includes a coherent and empirically plausible rationale. In some cases, there are readings on the syllabus beyond those discussed in class that may be helpful.

(a) the standard use of the revelation principle in designing auctions or incentive schemes
(b) the standard use of the Folk Theorem to characterize outcomes sustainable as implicit
     contracts in complete-information repeated games
(c) the use of subgame-perfect equilibrium to predict outcomes in infinite-horizon
     alternating-offers bargaining with complete information, as in Rubinstein (*Econometrica*
     1982)
(d) the use of sequential or perfect Bayesian equilibrium in models with "crazy types" to
     characterize reputation building, as in Kreps and Wilson, Milgrom and Roberts, or
     all of the above (*Journal of Economic Theory* 1982)
(e) the use of refinements such as the "intuitive criterion," as in Cho and Kreps (*Quarterly Journal
     of Economics* 1987), to derive unique predictions despite multiple equilibria in signaling
     games
(f) the use of rational expectations and/or perfect foresight assumptions in dynamic
     macroeconomic models to predict the effects of policy changes, as in the Lucas critique,
     Kydland and Prescott, "Rules versus Discretion…" (*Journal of Political Economy* 1977), or
     Barro, "Are Government Bonds Net Wealth?" (*Journal of Political Economy* 1974)
(g) the use of refinements such as risk-dominance to derive unique predictions despite
     multiple equilibria in macroeconomic models based on coordination failure like those
     discussed in Cooper and John (*Quarterly Journal of Economics* 1988)
(h) the use of iterated dominance in incomplete-information games with small idiosyncratic payoff
     trembles ("global games") to select among multiple Pareto-ranked equilibria in coordination
     games, as in Carlsson and Van Damme, "Global Games and Equilibrium Selection"
     (*Econometrica* 1993) and recent applications to bank runs and other problems, as in Morris
     and Shin, "Global Games: Theory and Applications," in *Advances in Economics and
     Econometrics* (Proceedings of the Eighth World Congress of the Econometric Society),
     edited by M. Dewatripont, L. Hansen and S. Turnovsky. Cambridge: Cambridge University
     Press (2003), 56-114; linked in manuscript at
     (http://www.princeton.edu/%7Esmorris/pdfs/paper_36_Global_Games.pdf)
(i) the use of ergodic evolutionary dynamics to characterize equilibrium selection in the
     "long run" in games played repeatedly in populations, as in Kandori, Mailath, and Rob; or
     Young (*Econometrica* 1993)