National Center for Risk and Economic Analysis of Terrorism Events
University of Southern California
Los Angeles, California

Experimental Game Theory
October 2011 to August 2012

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Charles Holt
University of Texas (Dallas)
University of Virginia

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Cooperative Agreement No. 2010-ST-061-RE0001
Department of Homeland Security
ABOUT CREATE
The National Center for Risk and Economic Analysis of Terrorism Events (CREATE) was the first university-based Center of Excellence (COE) funded by University Programs of the Science and Technology (S&T) Directorate of the Department of Homeland Security (DHS). CREATE started operations in March of 2004. This annual report covers the seventh year of CREATE funding from October 2011 to August 2012, under Cooperative Agreement 2010-ST-061-RE0001 from DHS. While the text of this report focuses on the seventh year, all data tables, publications, lists of participants, students, and presentations and events are cumulative from the inception of CREATE.

CREATE’s research mission is to develop advanced models and tools for risk assessment, economic assessment, and risk management to counter terrorism. CREATE accomplishes this mission through an integrated program of research, education, and outreach, spanning the disciplines of economics, psychology, political science, industrial and systems engineering and information science. CREATE develops models, analytical tools, methodologies and software, and tests these tools in case analyses, representing critical homeland security investment and policy decisions.

Due to the cross-cutting nature of research in risk, economics, and risk management, CREATE serves the need of many client agencies at the DHS, including the Transportation Security Agency, Customs and Border Protection, Immigration and Customs Enforcement, FEMA and the US Coast Guard. In addition, CREATE has developed relationships with clients in the Offices of National Protection and Programs, Intelligence and Analysis, General Council, Health Affairs, and Domestic Nuclear Detection. Using a mix of fundamental and applied research, CREATE faculty and students take both the long-term view of how to reduce terrorism risk through fundamental research and the medium-term view of how to improve the cost-effectiveness of counter-terrorism policies and investments through applied research.

Please visit www.create.usc.edu for more information.
Experimental Game Theory

This project experimentally investigates how individuals make decisions in strategic situations which are relevant to terrorism settings.

Project Technical Description:

1. **Keywords:** Strategic counterterrorism, game theory, laboratory experiments

2. **Theme Area:** Behavioral Economics

3. **Principal Investigator:** Rachel Croson, Catherine Eckel, Charles Holt

4. **Institution:** University of Texas (Dallas); University of Virginia

5. **Co-Investigators:** Steven Kimbrough and Howard Kunreuther (University of Pennsylvania)

6. **Brief Description:**
   
   This research project involves controlled laboratory experiments that will help us to model and predict terrorist behavior. These experiments identify where the rational actor and other economics models break down, and provide rough predictions for what individuals will do in those settings. Many of these experiments involve players choosing sites to attack or search, and thus illuminate the forces that influence terrorist groups in their selection of targets.

   We explore two main settings: attacker/defender games (also known as Colonel Blotto games), where an attacker and a defender each have a fixed amount of resources they can allocate among multiple sites, such as different cities, and interdependent security games, in which each player decides on a level of risk mitigation knowing that others’ actions will affect their own performance, which results in coordination games among defenders and/or attackers.

7. **Objectives:**

   The purpose of this research is to better understand how individuals behave in environments where the actions of one player impact the outcomes of the other, and to develop risk management strategies for coping with situations such as these. Our goals are: 1) To understand how individuals behave when they are faced with an adversary (e.g., terrorist) or counterpart who may take actions with potentially severe consequences; 2) To determine what decision rules individuals utilize to decide how to act in these situations; 3) To recommend improvements to the decision rules that individuals naturally use in order to better defend against attacks.

8. **Interfaces to CREATE Projects:**

   Professors Kimbrough and Kunreuther (along with other co-investigators) have previously been supported by the CREATE project to the Wharton Risk Center, “Experiments in Interdependent
Decision Making Under Uncertainty.” This proposed work builds on their previous research in the sense that our multi-defender and multi-attacker designs create security coordination games.

9. Previous or current work relevant to the proposed project:

Professors Croson, Eckel and Holt (along with other co-investigators) have funding from the National Science Foundation to support experiments in terrorism. This project includes lab experiments exploring three scenarios: strategic counterterrorism in situations where coordinated strategies between countries can lower costs and enhance success; inter-group conflict, where group are unequal in resources; and a specific variety of attacker/defender games (Arce et al, forthcoming). Eckel is involved in a proposal to develop video games to detect and mitigate the impact of cognitive biases in intelligence situations. Holt has worked with coauthors on laboratory tests of the Kunreuther/Heal model of interdependent security investment games, and has a proposal under review to extend this work. The ideas in this proposal are new, but additional funding from DHS would allow us to continue this work and continue to leverage previously-developed experimental designs and protocols.

10. Major Products and Customers:

Project deliverables will consist of a report that will present and interpret the results from the experiments. These results will (a) compare how individuals behave relative to game theoretic solutions and propose strategies for improving behavior to meet security objectives; and (b) suggest risk management strategies for increasing security, including economic incentives, well-enforced regulations and standards. In addition, Holt is in the process of developing instructional materials to create strategic attacker/defender environments, using classroom response systems (“clickers”) and standard web-based interfaces for laptops.

Customers: Coast Guard, Department of Defense, NSF. Products will include: Design of novel controlled experiments on both individuals and groups; risk management strategies for reducing risk of a catastrophic disaster or terrorist attack.

11. Technical Approach:

We investigated human behavior in two experimental settings that are relevant for terrorism. In the first setting, multi-site attacker/defender games (also known as Colonel Blotto games), an attacker and defender each have a fixed amount of resources they can allocate among multiple sites like different cities in the US. Attackers (defenders) decide how many of their resources they want to commit to attacking (defending) each of the cities. The side with the most resources allocated to a given city “wins” it (either with certainty or probabilistically) and collects some value (more for more important cities, less for less important cities). While the theory of Blotto games has been extensively developed (e.g., the earliest is Borel 1921 and the most recent, Goldman and Page 2008), relatively little is understood about how individuals play these games. We intend to compare observed behavior with that predicted by perfect rationality, identify how individuals systematically deviate and explore how those deviations might be exploited.

In our previously-funded research we have identified a baseline attacker-defender game, and conducted an experiment designed to examine how and whether individual behavior in this game
conforms to or deviates from its game-theoretic equilibria (under the standard assumption of fully rational agents). Here we propose new treatments (or variations on the game) which will enable us to examine whether and how individuals change their behavior in response to changes in the environment. One treatment involves multiple sites that have differing values to attackers and defenders – e.g., high value to an attacker but low value to a defender, or vice versa. For example, an airline terminal for a frontline country in another region may have high value for an attacker based in that region, but a defender may be more concerned with a domestic airline with high traffic volume.

Another approach involves interpreting “sites” as alternative demographic types that can be sent on an attack mission (joint work with Kydd, Sheremata, Razzolini, and Wilson). Some types are more reliable from the attacker’s point of view, in the sense that they would have a higher chance of success if they get past security checkpoints. But attackers may not send their most reliable agents if those agents are more likely to be searched at checkpoints. A Nash equilibrium for this setup can generate a “paradox of misaligned profiling” in which defenders search more reliable attacker types, but terrorists send less reliable types more often in equilibrium, but defenders are more likely to search the types that are more reliable attackers. A pilot experiment produced data that were roughly consistent with these counterintuitive predictions, but systematic departures from predictions need to be analyzed using follow-up experiments and behavioral modeling.

In addition, we are interested in the question of coordinated attacks. In the typical game, a single individual makes decisions for the attacker and a different but single individual for the defender. However, in the field, multiple attackers might coordinate an attack on a given city. We propose to investigate the conditions under which coordinated attacks are more or less successful, by varying conditions of communication, but also of differences in payoffs to the various attackers for capturing the target, and the ability of the defenders to coordinate as well.

A second setting involves interdependent security games in which each player decides on a level of risk mitigation knowing that others’ actions affect their own performance. Here we will compare how individuals and groups make decisions, and search for mechanisms to induce optimal protective activities.

We believe that understanding how individuals make decisions in these settings is central to a deeper understanding of national security. Of course, the participants in our laboratory studies will not be the same as the individuals making these national-security level decisions. Our goal is to identify psychological regularities (biases or heuristics) which are exhibited across a broad set of individuals and which will affect behavior in these settings. This project is relevant to national security in that it examines factors that influence terrorist groups in their selection of targets. It also helps us to identify where “rational actor” and other economic models break down in evaluating the probabilities of terrorist attacks or understanding terrorist behaviors. Once these regularities are identified, we can derive and describe strategies to improve an individual’s decision making (avoiding the biases) and to take advantage of the likely biased decision-making of his or her counterpart (exploiting the biases). The resulting advice will contribute to terrorism risk management efforts.
Economics experiments have several advantages in studying terrorism. An experiment is akin to a formal theoretical model, in that it is an abstraction from the world, simplifying in order to focus on key aspects or elements of a particular situation. Thus, like their mathematical cousins, experiments are not “realistic” simulations of national security situations, but rather are designed to isolate and examine separately the critical aspects of particular situations. This ability to isolate one or more key factors is one advantage of the experimental approach.

A second advantage is the superior control over the data generating process that the lab affords. The quality of data on terrorism is especially difficult to collect in the field, because of the incentives of each side (terrorists and governments) to misrepresent their information, and the consequences of revealing information (such as being arrested). In the lab we avoid these problems. Further, the lab provides the ability to build experimental designs that replicate most of the assumptions of formal models, thus testing the theory ‘on its own domain.’ As Plott (1986) has pointed out, if a model is true in the field, it should also be true in the lab. Finally, the lab provides data when access to the population of decision-makers would not be possible. Thus data from the lab can provide a first-level approximation of behavior by the relevant actors.

However, experiments have limitations as well. In particular, the question is always raised about whether the behavior of subjects (typically students) in a laboratory setting sufficiently resembles the relevant national security situation. We minimize this limitation in two ways. First, we do not merely examine behavior, but focus instead primarily on ‘comparative statics’ – i.e., how behavior changes when the conditions change. While those who choose to be terrorists are different from the general (US) population, and may play a given game differently, there is no reason to think that their reactions to changes in the game will be different. Second, we compare behavior of students with that of randomly selected members of the population who might be recruited for terrorist activities. This comparison allows us to check our assumption that comparative static behavior is constant across the two groups, as well as parameterize the likelihoods of observed actions among the population of interest.

Our goal is to identify when economic and game-theoretic models are good descriptions of behavior, and when behavior deviates from equilibrium predictions (Schotter 2005). Experiments are an especially useful methodology to identify robust deviations, due to psychological forces like heuristics and biases, which would presumably apply across a wide variety of individuals. Deviations are important to identify on two dimensions. First, a better understanding of behavior in response to a particular setting can help to improve our decisionmaking by de-biasing our own behavior. Second, it can bring a deeper understanding of others’ behavior. The ability to accurately predict the decisions of an opponent depends on accurate beliefs. An opponent who might at first appear to be irrational, instead becomes predictable once we understand the psychology underlying the decisions. Better predictions means we can better anticipate their actions, and choose better responses. Thus a better understanding of how individuals make choices in these situations will enhance our terrorism risk management efforts.

These systematic aspects of behavior can be used to build better models, and to design better policies. Counterterrorist policies must be designed to affect the behavior of people in the field, and a better understanding of how and to what extent their behavior deviates from the rational actor model is necessary for effective policy design.
12. References:


13. Major Milestones and Dates (revised from initial submission):

1. Develop and pretest human subject experimental protocols for each of the three sets of experiments. –August 1, 2011 (completed)

The remaining of the planned milestones were not completed due to funding withdrawl as of 10/1/2011

2. Perform first set of experiments. –November 1, 2011
3. Analyze results of first set of experiments. Produce embodied rules of subjects’ behavior. Revise plans and protocols for subsequent experiments. Revise requirements for the software testbed. –February 1, 2012
4. Perform second set of experiments. –March 1, 2012
5. Analyze results of second set of experiments. Produce embodied rules of subjects’ behavior. Consider: revision of plans and protocols for subsequent experiments, revision of requirements for the software testbed. –May 1, 2012
6. Perform third set of experiments. –June 1, 2012
7. Analyze results of third set of experiments. Produce embodied rules of subjects’ behavior. –July 1, 2012
8. Conduct computational experiments with embodied rules and analyze results. –August 1, 2012
9. Integrate findings and produce policy recommendations. –September 30, 2012
14. Budget:

Note that the funding for year 1 ($25,000) was received on April 15, 2011. Therefore the project was delayed somewhat. We requested (and received) permission to carry over the student support component to Year 2. Funding for Year 2 activities was not received.

<table>
<thead>
<tr>
<th></th>
<th>Year 1 remaining (5/1/2011 – 9/30/2011)</th>
<th>Year 2 Carryover from Year 1</th>
<th>Year 2 new request (10/1/2011 – 9/30/2012)</th>
<th>Project Total</th>
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<tr>
<td>Personnel</td>
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<td>1. PhD Student (9 months)</td>
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Budget Justification:

Personnel
Salary is requested for one PhD student for 9 months. We would like to support the student from September 1, 2011 through May 31, 2012. UT Dallas’s policy is to waive tuition charges for PhD students supported by external funding. Therefore there is no tuition request. The Fringe benefits rate is 25%.

Domestic Travel
Funds are requested for travel for the researchers to meet, and to present the work at academic conferences.

Other Direct Costs
Subject payments are requested as follows, averaging $20 per subject:
Baseline: 20 pairs of individuals = 40 subjects = $800
Coordinated attacks, 4 treatments, 20 groups of three each = 240 subjects = $4800
Coordinated Defense: 4 treatments, 20 groups of three each = 240 subjects = $4800.
15. CVs: (Note we have included three CVs: Croson, Eckel and Holt).

RACHEL TONI ALGAZE CROSON

A. Professional Preparation:

Harvard University, Economics, Ph.D., 1994.

B. Appointments:

University of Texas at Dallas, Professor, School of Economic, Political and Policy Sciences, 2007 – present. Director, Negotiations Center since 2007.


C. Recent relevant publications and working papers:


D. Recent grants:

NCSS/W: Substantive Expertise, Strategic Analysis and Behavioral Foundations of Terrorism. Rachel Croson (PI), Catherine Eckel, Daniel Arce, Chetan Dave. 9/09-8-11. $149,885. (BCS 0905044) (Eckel appointed PI 08/2010)

Collaborative with Charles Holt at University of Virginia. 09/09 – 08/11. $440,183 (BCS-0905060) (Eckel appointed PI, 08/2010)

CATHERINE COLEMAN ECKEL

A. Professional Preparation:

University of Virginia, Economics, Ph.D., 1983.

B. Appointments:


C. Recent relevant publications and working papers:


**D. Recent grants:**

It’s Not (Just) About the Money. PI, with Sheheryar Banuri. Collaborative with Angela de Oliveira. (SES-1062055) Collaborative with Angela de Oliveira; PI, with Sheheryar Banuri. 04/01/2011 – 03/31/2013. $216,007.


CHARLES A. HOLT

A. Professional Preparation:

Carnegie-Mellon, Economics, Ph.D., 1977

B. Appointments:

University of Virginia, Department of Economics (1983-), Chair and A. Willis Robertson Professor of Political Economy and Director of Veconlab (http://veconlab.econ.virginia.edu/admin.php

University of Minnesota, Department of Economics (Assistant Professor, 1977-82; Associate Professor, 1982-83).


C. Recent relevant publications and working papers:


D. Recent grants:


Collaborative Research: NSCC/SA: Experimental Analysis of Alternative Models of Conflict Bargaining (with K. Sieberg, D. Clark, W. Reed, T. Nordstrom, $137,473, 07/01/09-06/30/11.

Using Clicker Technology for Large-Scale Classroom Experiments in Economics, 07/01/08-06/30/11, ($144,229).

Progress Report/Final Report from prior funding

1. Research Accomplishments

Our original proposal involved $25,000 in the first year of the project (1/1/2011-9/30/2011), to be used for supporting PhD students and designing the experiments, and $20,000 in the second year (10/1/2011-7/31/2012) to be used for running the experiments, collecting and analyzing the data.

The first funding increment of $25,000 arrived in April, 2011 (rather than January, 2011 as anticipated). As planned, we supported one PhD student (with some carryover) and developed a detailed experimental design for the planned three sets of experiments. We identified potential parameters and informally pre-tested them.

However, due to financial constraints, funding for the second year’s activities was not provided. Thus, while we have designed the experiments, we have not collected or analyzed the data. We are in search of alternative funding sources in order to complete this project.

2. Applied Relevance

This research explores the objectives behind terrorist activities, the biases and heuristics that might contribute to the decision making of terrorists, and the potential effectiveness of alternative anti-terrorist policy interventions.

The purpose of this research is to better understand how individuals behave in environments where the actions of one player impact the outcomes of the other, and to develop risk management strategies for coping with situations such as these. Our goals are: 1) To understand how individuals behave when they are faced with an adversary (e.g. terrorist) or counterpart who may take actions with potentially severe consequences; 2) To determine what decision rules individuals utilize to decide how to act in these situations; 3) To recommend improvements to the decision rules that individuals naturally use in order to better defend against attacks.

In our previously-funded research (CREATE grant to Holt, and NSF grant to Eckel, Croson and others), we have identified a baseline attacker-defender game, and run an experiment designed to examine how and whether individual behavior in this game conforms to or deviates from its equilibria. We find, unsurprisingly, that individuals exhibit systematic (and potentially exploitable) deviations which could be used to construct more effective defenses.

3. Collaborative Projects

Professors Croson, Eckel and Holt (along with co-investigators Daniel Arce (UT Dallas) and Enrique Fatas (U. of Valencia)) have funding from the National Science Foundation to support experiments in terrorism. This project includes lab experiments exploring three scenarios: strategic counterterrorism in situations where coordinated strategies between countries can lower costs and enhance success; inter-group conflict, where group are unequal in resources; and a
variety of attacker/defender games. Eckel is involved in the early stages of a proposal (with computer engineers at UT Dallas) to develop video games to detect and mitigate the impact of cognitive biases in intelligence situations. Holt is working with AJ Bostian on programs to implement attacker defender games for large audiences, using classroom response systems “clickers”). Holt is also part of a team that is working on a theoretical and experimental analysis of profiling in attacker/defender games.

4. Research Products


The web-based Veconlab Multi-Site Attacker Defender game was further developed to assign value asymmetries between attackers and defenders. The incorporation of site-specific success probabilities also permits running experiments that are motivated by profiling strategies and optimal attacker responses to such strategies.

5. Education and Outreach Products

A beta version of the profiling attacker defender game for use with the classroom response systems has been tested in several classes at VCU this spring. This Veconlab Clicker software, written with Ruby on Rails, has the potential to be used with large classes.

6. Current Expenditures

The first year’s budget of $25,000 was spent supporting PhD students and travel to one conference for co-authors to meet as planned. The second year’s budget was not received.