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Analysis of bidding behaviors in non-monetary incentivized, real-time uniform auctions

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Analysis of Bidding Behaviors in Non-Monetary Incentivized, Real-Time Uniform Auctions

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By: Joshua H. Tiley

December 2010

Advisors: William Gates, Noah Myung

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13. ABSTRACT (maximum 200 words)

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This research compared user inputs across several subjects and determined which subjects to retain. Previous experiments compared participants' bids to computer simulated "optimal" bids; it was hard to say how, or if, bidding strategies would change if competing with other live players.

There are two issues when dealing with optimal bidding strategies. The first is correct choosing non-monetary incentives. We found that 70% of these choices were made correctly. The second involves the salary requested after choosing non-monetary incentives. The salary requests were above the optimal bids. Coupled with the fact that non-monetary incentives were generally chosen correctly, this shows that most participants miscalculated their salary request. Other controls and instructions should be introduced prior to implementing a formal retention auction.

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ANALYSIS OF BIDDING BEHAVIORS IN NON-MONETARY INCENTIVIZED, REAL-TIME UNIFORM AUCTIONS

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2010

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LIST OF ACRONYMS AND ABBREVIATIONS

CRAM	Combinatorial Retention Auction Mechanism
FY	Fiscal Year
GSBPP	Graduate School of Business and Public Policy
IRB	Institutional Review Board
LAN	Local Area Network
NEC(s)	Navy Enlisted Classification(s)
NMI(s)	Non-monetary Incentive(s)
PTS	Perform to Serve
SRB	Selective Reenlistment Bonus
U.S.	United States
Ztree	Zurich Toolbox for Readymade Economic Experiments

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First and foremost, I would like to thank my Lord and Savior, Jesus Christ, for giving me the patience and endurance to complete this work. I would also like to thank my advisors, Bill Gates and Noah Myung, for providing the guidance and technical expertise necessary throughout this project. I also offer my warmest gratitude and love to my beautiful wife, Carole, for her encouragement and patience during my time at NPS.

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I. INTRODUCTION

A. PURPOSE

The Selective Reenlistment Bonus (SRB) has been effectively used to shape force structure and personnel levels. The SRB program allows the Navy to forecast prospective losses against required numbers. This enables the service to provide bonuses in certain ratings that incentivizes reenlisting and aids in maintaining desired personnel levels. However, the current program exhibits limitations that increase the cost to the Navy by providing force levels that are not commensurate with current manpower requirements.

This research investigates the practicality of auction mechanisms as retention tools. Past research dictates that personnel bid rationally against computer generated bids whose feedback demonstrates ideal bidding. In purely competitive bidding, subjects will receive feedback that may not reflect ideal strategies resulting in retention costs that may fall well above or below the market clearing cost. An experiment designed to test this behavior was conducted and analyzed to determine implementation potential and identify further controls to shape outcomes.

B. BACKGROUND

The Navy, along with the other armed services, continually fights the affects of economic surge and recession, budget constraints, and natural personnel turnover in an effort to maintain manpower levels at desired "end-strength." Subsequently, mandated quantities of specialized ratings require particular attention from manpower specialists to maintain a lean diverse force. These specialized, highly technical, ratings demonstrate large fluctuations depending on the civilian economic environment and current promotion limitations.

Forecasting retention bonus levels based on the above socio-economic factors is extremely difficult. The resultant manpower surpluses and deficits cause excessive burdens to manpower costs, military efficiency, and equipment. Current forecasting

techniques are less precise than retention auction mechanisms because, in theory, auction mechanisms provide the exact desired manpower at the lowest price to the employer.

C. RESEARCH QUESTIONS

The research addresses the following questions:

1. Primary Question

What bidding strategies are adopted within a uniform-price real-time auction mechanism employing non-monetary incentives and human subject competition?

2. Secondary Questions

a. Does competition between human subjects alter bidding strategies as opposed to bidding against predetermined computerized values?

b. Is the real-time auction viable based on alterations or consistencies in subjects' bidding strategies?

D. SCOPE AND LIMITATIONS

This project includes comparative analysis of real-time competitive uniform auctions and past iterations of the Combinatorial Retention Auction Mechanism (CRAM). It also briefly discusses the current SRB program and its limitations. Past research in the field and experimental results will provide the required data to answer the research questions. This project will investigate Non-monetary Incentives (NMI) in a non-specific manner that will maintain continuity of experimentation for all participants. The study focuses primarily on implementing an improved SRB program using auction mechanisms incorporating NMIs.

E. CHAPTER OUTLINE

Chapter I describes the purpose of this project as well as the questions it intends to address. Chapter II is a background on military retention and compensation. Chapter III is a literature review that addresses past research into the field of retention auctions. It

also focuses on the current problems with the SRB system and retention in critical ratings. Chapter IV describes the CRAM concept and its application to this experiment and project. Chapter V focuses on the materials and methods used in this experiment and project. Chapter VI includes a discussion of the experimental design. Chapter VII includes the results of the experiment and recommendations for future study and improvement.

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II. MILITARY RETENTION AND COMPENSATION

A. BACKGROUND INFORMATION

Manpower retention initiatives within the United States Navy help maintain desired force levels in critical ratings facing frequent turnover attributed to favorable outside job offers. The natural ebb and flow of the civilian economic environment affects the monetary investment required to maintain personnel levels. A market-clearing price must be defined for each reenlistment group throughout the year. Sailors in technical ratings generally receive higher reenlistment bonuses because the private sector values their skills and the Navy has incurred a higher training cost. Conversely, during times of economic downturn, the Navy often observes men and women with high technical acumen joining the military, as job offers may be low to non-existent in the civilian sector.

B. PERSONNEL COSTS

Personnel costs are the second largest portion of the defense budget at $138.5 Billion for Fiscal Year (FY) 2011, accounting for more than 25% of the total budget.[1] Military Personnel trails only Operation and Maintenance (O&M) and even exceeds Military Procurement by a full 5% as a ratio of appropriation category to overall budget request.[2] Personnel funding rose 2.6% from FY 2010 to 2011, while O&M and procurement rose between 7.7 and 8.5 %.[3] The current lull in military personnel funding can be attributed to the steady decline of force strength as a result of the Joint Chiefs of Staff (JCS) guidance to attain the most efficient end-strength while maintaining a capable

[1] Department of Defense, "Summary of the DOD Fiscal 2011 Budget Proposal," Defense GOV, http://www.defense.gov/news/final%20press%20release%20v3%20%201.pdf.

[2] Department of Defense, "Summary of the DOD Fiscal 2011 Budget Proposal," Defense GOV, http://www.defense.gov/news/final%20press%20release%20v3%20%201.pdf.

[3] Ibid.

military. The JCS guidance tasks the military to, "articulate a vision for the future force, including an estimate of future threats and the military requirements to counter those threats."[4]

Bonuses account for approximately 2.5–3% of the Department of Defense personnel budget for 2011, or approximately $4 billion.[5] The growth of O&M and procurement is a product of the two-front war in which the U.S. is currently involved; one assumes that once the U.S. withdraws from the region, the current upswing will turn into declining cost deltas in both O&M and procurement. Conversely, the current military "end-strength" is on par with desired peacetime service levels. The JCS' goal is to provide full spectrum forces that do not require downsizing or buildup following or prior to a conflict.

C. TRENDS IN MANPOWER LEVELS

The historically massive departure of service members following major conflicts, both voluntarily and involuntarily, creates knowledge and leadership vacuums that persist well into future conflicts. The draft's demise and advent of the all volunteer force affords some stability within the ranks due to the voluntary nature of enlistments; however, competition with civilian jobs makes it necessary to institute a bonus program to further alleviate fluctuations in manning. The current state of the nation's economy requires new methods of forecasting bonus levels, as existing service members are likely to stay in the military under the increasingly uncertain civilian job market. Many services have chosen to defer reenlistment bonuses for many specialties, due in large part to the unfavorable economic outlook. However, we cannot assume a stagnant economy in perpetuity and, absent new bonuses, personnel shortfalls will resume.

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[4] Mike Mullen, "CJCS Guidance 2008-2009," Small Wars Journal, 4, http://smallwarsjournal.com/documents/cjcsguidance.pdf..

[5] Office of the Under Secretary of Defense Comptroller, "Department of Defense Budget Fiscal Year 2011," Defense Comptroller, http://comptroller.defense.gov/defbudget/fy2011/fy2011_m1o1rf1.pdf.

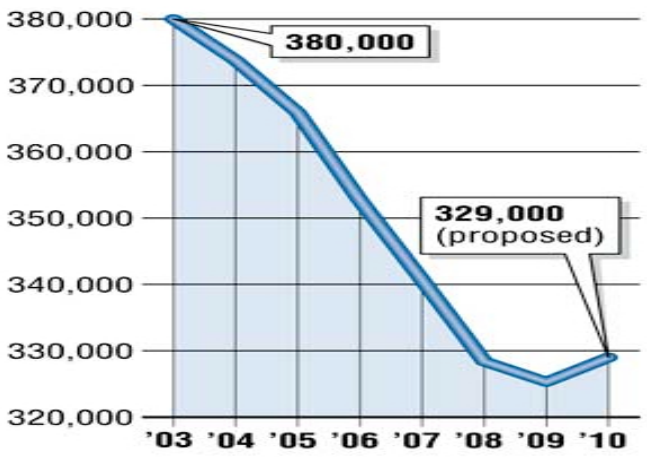

Figure 1. Navy Manpower Trends 2003–2010 (projected)[6]

Personnel costs and defense budgeting concerns led to a congressionally authorized "end strength" for all services. The Navy's authorized end strength is 329,000[7] sailors, forcing the naval service to reduce manning on ships and equipment to minimal levels. These levels cannot feasibly be reduced any further without first reducing the number of navy ships and commands. The Department of the Navy cut approximately 8,000-10,000 personnel per year between 2002 and 2009 to reach the mandated end strength.[8] While fluctuations to end strength have occurred amongst the Army and Marine Corps as a result of the conflicts in Iraq and Afghanistan, the Navy numbers have stayed constant, in large part due to consistency of operations. Consequently, Navy retention costs vary with the civilian economic climate, but rarely fluctuate due to wartime end-strength increases.

[6] Navy Personnel Command, 2009.

[7] Gerry Gilmore, "Navy Stabilizes Force as it Nears End-Strength Goal, Admiral Says," Navy Times, http://www.navy.mil/search/display.asp?story_id=43597.

[8] Gerry Gilmore, "Navy Stabilizes Force as it Nears End-Strength Goal, Admiral Says," Navy Times, http://www.navy.mil/search/display.asp?story_id=43597.

D. NAVY SRB PROGRAM

Navy instruction 1160.8A states, "SRB is the Navy's primary monetary Force shaping tool to achieve enlisted retention requirements in ratings, Navy Enlisted Classifications (NECs) and skills."[9]

The program has proven influential in efficiently retaining sailors in many of the Navy's most technically difficult ratings. The system itself is relatively agile, with bonuses reevaluated annually and monetary awards removed for reenlistments once rating quotas have been filled for the year. The Naval Personnel Command evaluates many complex factors to meet retention goals within varying economic climates.

Navy directives to the Personnel Command:

- Reviews are conducted at least annually to determine which ratings/NECs/skills will be authorized SRBs.
- Award levels are changed in response to market forces as retention changes in ratings, NECs and skills.
- Changes to the list of SRB eligible ratings/NECs/skills and respective award levels will normally be promulgated by naval message[10]

The program's importance cannot be overstated. Even in the post recession economy of FY 2011, the Navy plans to commit to bonuses for 17,000 sailors within 135 critical ratings, with individual awards up to $90,000.[11] Present economic indicators logically dictate removing most SRB awards; however, the need for specialized skills in both the civilian and military contracting sector constantly cause large retention voids regardless of market forces.

Criteria for determining SRB:

- Severe under manning in three or more adjacent year groups in the bonus zone.

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[9] U.S. Navy, *OPNAV Instruction 1160-8A: Selective Reenlistment Bonus Program* (Washington, DC: Headquarters United States Navy, 2007), 2.

[10] U.S. Navy, *OPNAV Instruction 1160-8A: Selective Reenlistment Bonus Program* (Washington, DC: Headquarters United States Navy, 2007), 2.

[11] Chief of Naval Personnel, "Navy Announces Updates to Selective Reenlistment Bonus," Navy Times, http://www.navy.mil/search/display.asp?story_id=55844.

- Severe under manning as shown by a history of shortages in past years or projected for future years.
- High training and replacement costs.
- Relatively arduous or unattractive skill compared to the other ratings/NECs/skills or civilian alternatives.
- Skill is essential to the mission of the Navy.
- A reasonable prospect of enough improvement in retention in response to the award to justify the cost.[12]

1. Reenlistment Criteria and Bonus Zones

The SRB program does not allow for all military personnel to reenlist for a bonus. Those sailors who have more than 14 years of service are ineligible for bonuses under the SRB program.

Specifically,

> SRB eligibility is limited to members with 17 months of continuous active duty (other than for training) but not more than to 14 years of active duty. This time period has been further divided into three zones as described in Table 1.[13]

RULE	A	B	C	D	E	F
	Zone (note 1)	You must have completed	But not more than	Years of total active military service (note 5) on the date of reenlistment or operative date of qualifying extension, and the reenlistment or extension plus the prior active service	Must equal at least	Years of total active service
1	A	17 months (note 2)	6 (note 3)		6	
2	B	6 years	10 (note 4)		10	
3	C	10 years	14		14	

Table 1. Navy SRB Zones[14]

[12] U.S. Navy, *OPNAV Instruction 1160-8A: Selective Reenlistment Bonus Program* (Washington, DC: Headquarters United States Navy, 2007), 2.

[13] U.S. Navy, *OPNAV Instruction 1160-8A: Selective Reenlistment Bonus Program* (Washington, DC: Headquarters United States Navy, 2007), 5.

[14] U.S. Navy, *OPNAV Instruction 1160-8A: Selective Reenlistment Bonus Program* (Washington, DC: Headquarters United States Navy, 2007).

Each service member is allowed one reenlistment bonus per zone. As a result, the maximum number of reenlistment bonuses per service member during a career is three. This is in great contrast to a civilian business system that generally renegotiates contracts on a yearly or bi-yearly basis. However, once outside the bonus zones, sailors may reenlist for non-monetary incentives discussed with their detailers. These alternatives to monetary incentives are discussed in chapter 3.

2. Perform to Serve Program

The Perform to Serve (PTS) program runs in concert with the SRB program, vetting sailors prior to allowing them to reenlist. This program gives reenlistment precedence to sailors based on regularly scheduled evaluations and awards.

The purpose of PTS is to provide,

> …a long-term force shaping tool that aids in leveling rating manning between overmanned and undermanned ratings, while managing the quality of reenlistment applicants by controlling the authority for reenlistment.[15]

Historically, the SRB system allowed most sailors to reenlist simply by date requested and on the merits of decent conduct and average performance. Problems arose when outstanding sailors requested reenlistment after the rating quota had been met for the year. This caused the outstanding sailors to lose out on bonuses simply because of bad reenlistment timing. Many of those sailors felt snubbed by the system and chose to leave the Navy, creating a knowledge vacuum and loss of major investments in personnel training and experience. The PTS program serves to rank sailors in order of preference for reenlistment to mitigate the SRB system shortcomings.

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[15] U.S. Navy, *Military Personnel Manual 1440-060: Perform to Serve* (Washington, DC: Headquarters United States Navy, 2006), 1.

3. Weaknesses

The SRB program's inherent weaknesses stem from the inability to forecast retention intentions with complete accuracy. As bonuses become available, sailors who may have been counted as prospective losses choose to stay due to various factors.

Factors that affect prospective retention decisions:

- Status of outside job offers
- Size of bonus incentive
- Job security
- Options for continued training and education
- Health Care
- Housing costs and allowances
- Arising personal issues

There is no feasible method to calculate or estimate changes in preferences throughout the FY without continually monitoring each member that qualifies for reenlistment. This system characteristic makes it impossible to obtain a market-clearing price for bonuses that does not lead to over manning or personnel shortfalls. Imprecise manpower retention predictions lead to over- or undermanned ratings, inaccurate bonuses, and the potential loss of highly qualified sailors. It typically leads to bonuses that are higher than required for proper retention given a certain period within the fiscal year.

The trend of over manning that is historically prevalent within the services demonstrates that the services typically overestimate the required bonus. Consequently, the use of past data and future assumptions continue to exacerbate the issue of errant forecasting. Excesses and shortfalls in manning increase military costs and can compromise readiness. When excesses arise, the military must pay the excess sailors' basic pay, special pays, and benefits such as health and dental care. When shortfalls occur, the Navy is forced to fill the knowledge and leadership void by training new sailors up to the level of those that separated or risk equipment deterioration, loss of manpower required for national tasking, and delays in deployments.

E. CHAPTER SUMMARY

Many trends in the civilian economy influence attraction and detraction from reenlistment. Current Navy SRB standards dictate that not all sailors will even meet the requirements to receive a bonus and even fewer will receive one due to overmanned ratings. The general lack of continuity within the Navy retention system in complex economic environments makes it nearly impossible to predict the cost required to efficiently maintain end strength numbers. These shortfalls not only incur a high monetary cost to the Navy's personnel budget—they quite frequently create vacuums in expertise and leadership that cost far more in the long run than properly negotiated bonuses at the end of a sailor's term with the service.

III. LITERATURE REVIEW

A. INTRODUCTION

Monetary incentives are currently the only defined means of encouraging retention amongst military personnel. However, options such as geographic security, advanced schooling, etc., also entice sailors to maintain their service. These incentives vary between sailors and are usually offered when the sailor falls outside of the designated zones required for a reenlistment bonus. Coupling non-monetary incentives (NMIs) and monetary incentives into a bonus package can reduce the cost of retaining a sailor by utilizing military infrastructure to provide a higher value than what could be obtained through simple monetary bonuses.

B. MONETARY REENLISTMENT BONUSES

An all-volunteer force leads to a very pronounced need for reenlistment incentives to maintain a capable, experienced military. To this end, "the most straightforward approach to retention bonuses is to only use monetary incentives."[16] The Navy currently offers bonuses ranging from a couple thousand dollars to over $70,000 for rates of high technical acumen and those of critical need. Even so, a former Naval Postgraduate School study indicates the desire of sailors to leave the Navy regardless of the value of an SRB package.[17] One of the methods to deal with the diminishing attractiveness of monetary reenlistment packages amongst sailors is to deliver incentives tailored to individual sailors. Monetary incentives simply do not address the unique requirements of sailors and, as a result, many sailors look elsewhere for employment when their enlistments lapse.

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[16] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, "The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives."(Technical report, Naval Postgraduate School, 2008).

[17] Constance M. Denmond, Derek N. Johnson, Chavius G. Lewis and Christopher R. Zegley, "Combinatorial Auction Theory Applied to the Selection of Surface Warfare Officer Retention Incentives" (MBA professional report, Naval Postgraduate School, 2007).

C. NON-MONETARY REENLISTMENT INCENTIVES

Non-monetary incentives are those that are non-cash, but have a non-trivial market value.[18] These incentives do not include intrinsically valued merits, such as service to country as, by definition, the intrinsic value of that service is not defined by perceived equivalent monetary value. While it has been shown that employees generally prefer monetary to non-monetary incentives,[19] studies infrequently explore synergies between the two in combination.

D. EXPERIMENTAL ECONOMICS

Webster's dictionary describes experimental economics as, "the application of the laboratory method to test the validity of various economic theories and to test bed new market mechanisms."[20] The application of these theories involves human subjects competing in controlled environments. However, the issue of false equilibria emerging within economic experiments makes it difficult to determine exactly how efficiently subjects will react to the experimental environment. False equilibria are any perceived strategies that subjects use to justify a departure from cooperation during game theory experiments. We naturally assume that rational behavior (greatest personal good) will be the main driver of strategy in economic experiments. If the experiment is cooperative, for example, the subjects should cooperate to achieve the greatest good possible.

E. TYPES OF ECONOMIC EXPERIMENTS

Three distinct types of experiments pervade experimental economics. Each of the three, individual decision theory experiments, game theory experiments, and price theory experiments provide distinctive advantages over their counterparts, depending on the experiment and results required.*

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[18] Scott Jeffrey, "The Benefits of Tangible Non-Monetary Incentives" (Graduate School of Business, University of Chicago, 2003), 1.

[19] Ibid.

[20] Definition taken from http://www.websters-online-dictionary.org/.

*__NOTE__: Price theory and individual decision theory have been covered extensively in other theses dealing with the CRAM concept and those involved with other branches of military retention (Hahn, 2010; Browning and Burr, 2009; Zimmerman, 2008).

1. Game Theory Experiments

Game theory is a class of mathematical models that describes rational agent interaction.[21] These models focus on the subjects' rational decision-making while not allowing collusion. However, the success or failure is predicated on honest valuation of their current state. The typical example for academia is the "Prisoner's Dilemma."

In the prisoner's dilemma, authorities have arrested two subjects. The police suspect one of them in the commission of a major crime, but have arrested both on a lesser charge allowing them time for questioning.

	Confess A	**Stay quiet** A
Confess B	6 / 6	10 / 0
Stay quiet B	0 / 10	2 / 2

Figure 2. Prisoner's Dilemma[22]

[21] Douglas D. Davis and Charles A. Holt, *Experimental Economics* (New Jersey: Princeton University Press, 1993).

[22] Amanda G. Browning and Clinton F. Burr, "Monetary and Non-Monetary SWO Retention Bonuses: An Experimental Approach to the Combinatorial Retention Auction Mechanism (CRAM)," (MBA professional report, Naval Postgraduate School, 2009).

The prisoner's dilemma is illustrated in Figure 8 above. The police have offered plea bargains to both in exchange for information about and any implications as to the perpetrator of the crime. If neither subject confesses, they both receive two years in prison. If both confess, they receive six-year sentences. However, if one confesses and the other does not, the one that confessed will receive no jail time while the other is incarcerated for ten years.

The whole premise behind the prisoner's dilemma is that without knowledge of another's strategy, one must decide whether to confess or stay quiet. Because the jail time is less if both remain silent, that would be the preferred outcome. The dilemma is that without cooperating, both prisoners do better by confessing whether the other prisoner confesses or stays quiet. Thus, without cooperating both prisoners want to confess while both should stay quiet if they could cooperate. The inherent decision-making processes of risk neutral individuals—members that show propensity to confess—make it much more difficult to make sound choices with such complex results.

F. INFLUENCES AND IRRATIONALITY

It has been shown that subjects process various other forms of influences from their environment during economic experiments. These influences are known as "type uncertainty."[23] Players attempt to figure out the strategies of other subjects and exploit them for their benefit. "The idea is that if players are uncertain about other players' types, then the possibility emerges that players will mimic a type different from their own."[24] However, the issue of false equilibria emerging within economic experiments makes it difficult to determine exactly how efficiently subjects will react to the experimental environment. We naturally assume that rational behavior (greatest personal good) will be the main driver of strategy in economic experiments. If the experiment is cooperative, for example, the subjects should cooperate in order to achieve the greatest personal good possible.

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[23] Elizabeth Hoffman, Kevin A. McCabe, and Vernon L. Smith, "Behavioral Foundations of Reciprocity: Experimental Economics and Evolutionary Psychology," *Economic Inquiry* 36 (1998): 336.

[24] Elizabeth Hoffman, Kevin A. McCabe, and Vernon L. Smith, "Behavioral Foundations of Reciprocity: Experimental Economics and Evolutionary Psychology," *Economic Inquiry* 36 (1998): 336.

G. REAL-TIME EXPERIMENTATION

Previous experiments conducted for CRAM relied on human subjects in competition with preset database values.[25] These experiments yielded extremely valuable data on the ability of participants to choose rationally. In reality, we assume the competition happens among a group of people, devoid of collusive affects, and without prior knowledge of rational bidding strategies relative to game theory experimentation. Because these earlier experiments gave feedback based on predetermined values, most subjects recognized the optimal bidding strategy rather quickly and found continued success throughout the process.

Based on type uncertainties[26] and, absent any knowledge of appropriate bidding strategies, human subjects in real-time competition may exhibit irrational behaviors not established in previous tests.

H. CHAPTER SUMMARY

Extensive testing of retention methods needs to be conducted prior to fielding due to the variations in risk-taking among sailors. The uncertainty with respect to levels of cooperation and truth revealing could lead to inefficiencies in the retention system. The results of this project aim to identify any weaknesses in the CRAM concept and recognize further controls that may be required if utilized by the U.S. Navy.

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[25] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010).

[26] Elizabeth Hoffman, Kevin A. McCabe, and Vernon L. Smith, "Behavioral Foundations of Reciprocity: Experimental Economics and Evolutionary Psychology," *Economic Inquiry* 36 (1998): 336.

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IV. CRAM

A. RETENTION AUCTIONS

Simple monetary retention auctions address the overarching problem of retaining the precise number of personnel desired for any given retention cycle. What this auction fails to address is the ability to provide exact retention while offering the potential for lower total cost. Non-monetary incentives offer a method to provide higher compensation value to reenlistees at an equivalent or lower cost than that of a simple monetary auction. This project narrows the scope of experimentation to a uniform auction with menu style NMI elicitation because this method affords the opportunity to lower cost over traditional auctions.[27]

There are many characteristics that define retention auctions. Some of these include the number of bidders, number of sellers, well-defined supply and demand systems, as well as complex bidding rules and auction results. The auctions dealt with within this project, known as labor retention auctions, allow the employer (buyer) to engage in a reverse auction with its employees (sellers) that streamlines the retention process while providing optimal cost for those retained. Figure 3 demonstrates the unique characteristics of this auction.

[27] Constance M. Denmond, Derek N. Johnson, Chavius G. Lewis and Christopher R. Zegley, "Combinatorial Auction Theory Applied to the Selection of Surface Warfare Officer Retention Incentives" (MBA professional report, Naval Postgraduate School, 2007).

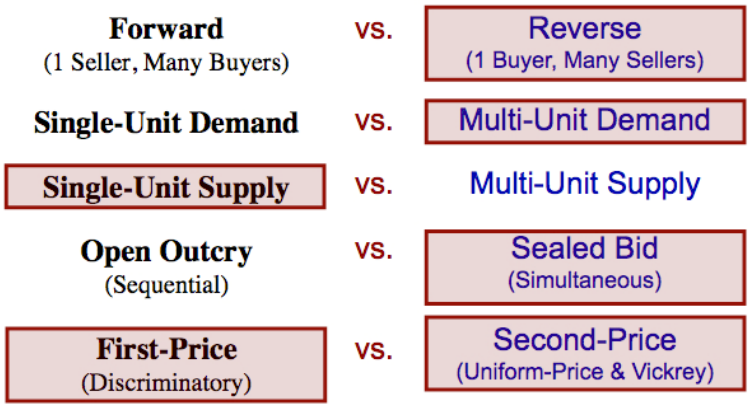

Figure 3. CRAM Characteristics[28]

B. COMBINATORIAL RETENTION AUCTION MECHANISM (CRAM)

CRAM combines monetary and non-monetary incentives in a reverse, truth-revealing auction enabling the Navy to retain the exact number of personnel desired at the optimal cost. This mechanism utilizes a reverse auction in which subjects enter bids based on perceived willingness to serve coupled with the personal worth of any NMIs offered. Preliminary economics experiments have been conducted with CRAM to better understand human bidding behavior in this context. In these preliminary experiments, participants compete against computerized decisions that reflect optimal bidding strategies. To generate a baseline monetary worth, the computer assigns each experimental participant an alternate job offer from a rival employer (Company B). This serves to establish a basic personal worth that is then coupled with the personal value for each NMI offered by the subjects' current employer (Company A), also established by the computer program.

[28] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, "The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives."(Technical report, Naval Postgraduate School, 2008).

Sailor #	Min. $ to Retain	Incentive 1 Value	Incentive 2 Value	Total Incentive Cost	Total Incentive Value	Revised Min. $ to Retain	Total Cost to Retain	Cash Bonus	Total Value Received
1	$80K	$40K	$10K	$20K	$40K	$40K	$60K	$60K	$100K
2	$90K	$10K	$30K	$20K	$30K	$60K	$80K	-	-
3	$100K	$30K	$40K	$40K	$70K	$30K	$70K	$40K	$110K

- Suppose Navy wants to retain 2 out of these 3 sailors
- Outcome with cash bonus only under 2nd-price auction
  - Each retainee receives 1st-excluded cash bid = $100K
  - Total cost to retain = 2 × $100K = $200K
  - Total surplus for retainees = ($100K - $80K) + ($100K - $90K) = $30K
- Suppose cost to Navy of each of 2 non-monetary incentives = $20K
- Outcome with Combinatorial Retention Auction Mechanism (CRAM)
  - Cost per retainee = 1st-excluded total cost to retain = $80K
  - Total cost to retain = 2 × $80K = $160K
  - Total surplus for retainees = ($100K - $80K) + ($110K - $100K) = $30K

Figure 4. CRAM Example[29]

C. PRICING METHODS IN PURELY MONETARY RETENTION AUCTIONS

Within the CRAM concept, there are two distinct Pricing methods that determine the monetary compensation each retained sailor will receive; each method influences rational bidding strategy in a very different way.

1. Uniform Pricing Method

The uniform pricing method provides each retained sailor with an equivalent monetary salary/bonus. The monetary bonus awarded to each retained sailor is equal to the highest salary bid of those retained (set in practice by the salary requested in the first excluded bid). For example, if the highest salary bid of those retained is $50,000 then all sailors retained would receive a monetary value of $50,000. This method initially appears to yield a high cost to the military because you are ”overpaying” sailors willing to reenlist

[29] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, “The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives.”(Technical report, Naval Postgraduate School, 2008).

for smaller bonuses. In uniform price auctions with NMIs, the total cost of the compensation provided each retained sailor equals the total cost of the compensation requested by the first excluded bidder, including both the monetary compensation awarded and the cost for any NMIs provided.[30]

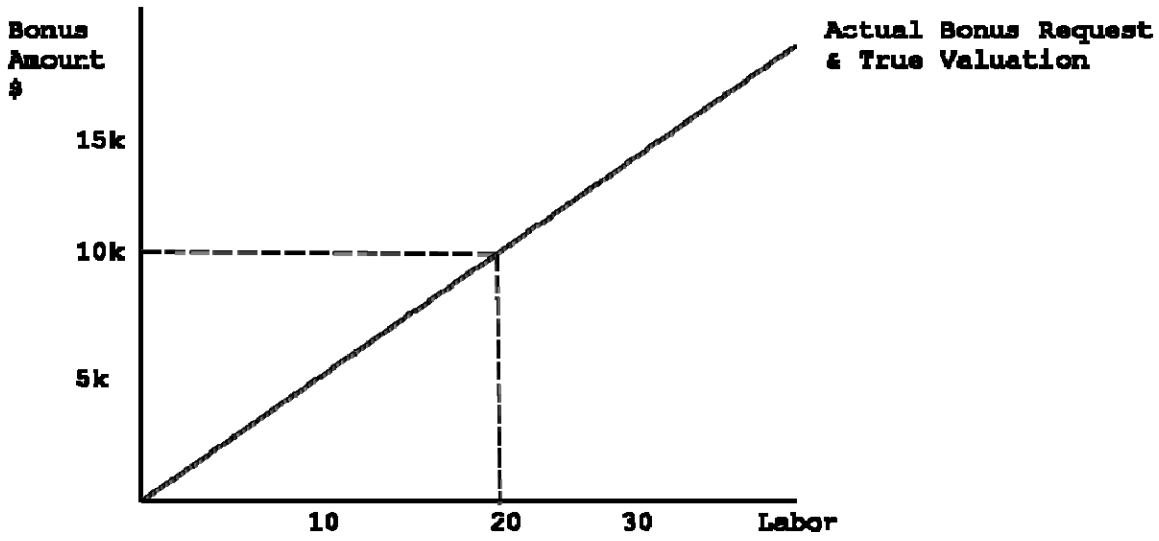

Figure 5. First Price (Uniform Auction)[31]

2. Discriminatory Pricing Method

In the discriminatory pricing method, each retained sailor receives only the monetary bonus requested in his or her retention bid. In this case, if the highest salary bid of those retained is $50,000 and the lowest is $15,000, the retained sailor with the highest bid would receive $50,000 and the sailor with the lowest bid $15,000. In a discriminatory price auction, the optimal bidding strategy is to overstate your minimum required bonus,

[30] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010), 26.

[31] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010).

where the size of the overstatement depends on your estimate for the highest acceptable bid and your attitudes toward avoiding risk; the greater your aversion to risk the less you overstate your bid.[32]

Discriminatory pricing within the military causes issues amongst reenlistees by creating large margins in incentive packages attributed to differences in outside employment options, preferences for military service and risk aversion when bidding. Ironically, sailors most willing to serve are rewarded with lower retention bonuses. Discriminatory price auctions also do not have the benefit of being truth revealing, which would allow trend analysis for future retention projections and opportunity costs.[33] While the discriminatory price auction would appear to reduce the military's retention costs by not "overpaying" those more willing to serve, auction theory and actual experience indicates that both discriminatory and uniform price auctions involve approximately the same cost, as long as bidders are not significantly averse to risk. As such, a discriminatory auction offers the same overall cost as a uniform auction; better termed as the revenue equivalence theory.[34]

32 Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010), 28.

33Hahn, 31.

34 Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010), 31.

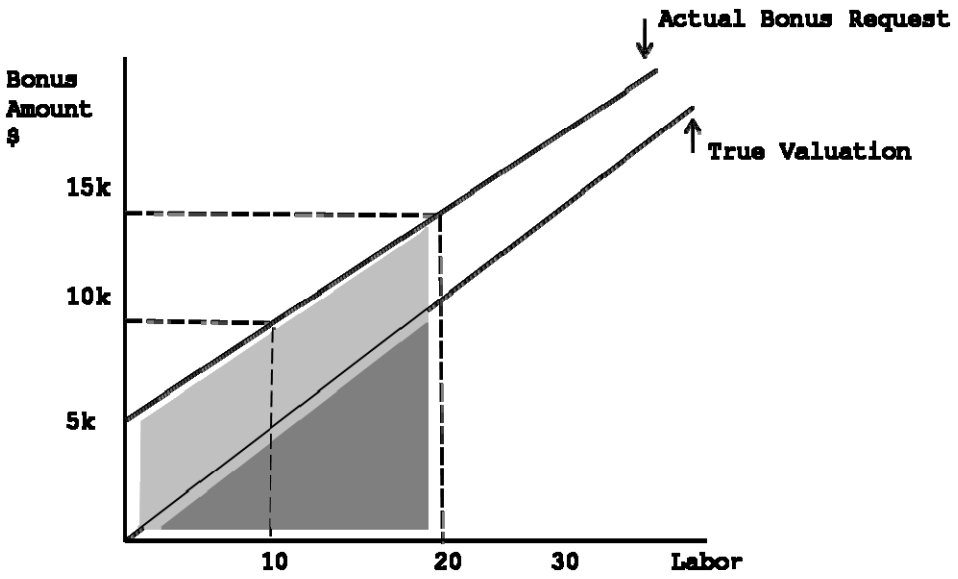

Figure 6. Second Price (Discriminatory Auction)[35]

D. NMI ELICITATION METHODS

There are two distinct manners used to elicit NMI bids in CRAM, yielding four possible CRAM experimental methods (2 Pricing Methods X 2 NMI Elicitation Methods).

[35] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010).

	Private value elicitation method	
Pricing method	Uniform-Price Auction + Menu Approach	Uniform-Price Auction + Bid Approach
	Discriminatory Auction + Menu Approach	Discriminatory Auction + Bid Approach

Figure 7. Pricing and NMI Elicitation Matrix[36]

1. Menu Approach

The menu approach reveals Company A's cost of each NMI to the bidder. It is then up to the subject to either take or reject the incentive based on their personal NMI valuation. If the bidder accepts an NMI and is retained, the NMI cost is included in the cost to retain that subject when determining the lowest cost employees to retain. For example, we assume that the NMI cost to the corporation is represented by the variable "Nc" and the subject's personal valuation of the NMI is represented by the variable "Nv." If the bidder is rational, they will reject the NMI if (Nc > Nv). Again, assuming rational bidding, the bidder will accept the NMI if (Nc <= Nv). In the menu approach, any NMI selected by the bidder will automatically be awarded to any retained employee as the cost was revealed during bidding.

2. Bid Approach

The bid approach does not reveal the company's cost to provide the NMI. It simply asks for a numerical valuation based on a specific NMI or NMI combination. In

[36] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, "The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives."(Technical report, Naval Postgraduate School, 2008).

this approach, the bidder may be given the NMI "1 year of childcare." Based on personal history, the bidder generates a value they would require to provide themselves with 1 year of childcare. In this case, we assume the same variables as the menu approach (Nc, Nv). However, in the bid approach the subject enters a value for Nv. If (Nv < Nc) the NMI is not awarded because it costs the employer more to provide the service than the employee's value of said service. The NMI is only awarded where (Nv >= Nc), as the subject's value is at least equal to the cost required to provide the service. In the bid method, the subject's monetary bonus is reduced by the employer's cost to provide that NMI.

The experiments designed for this report are uniform price, menu method auctions.

E. NON-MONETARY VALUE AND COST SAVINGS

Non-Monetary incentives can potentially save the military money if they provide a service that the sailor values more than the cost of supplying that service. For instance, the Navy may provide childcare at no cost as a non-monetary incentive to a sailor for a term equal to that of their reenlistment. We will assume the Navy's cost to provide the service is $5,000 and the sailor values the childcare at $7,000. If the sailor were offered a simple monetary incentive, his request might be the $7,000 required to satisfy his childcare requirement. Because the Navy is able to cover that requirement for $2,000 less ($7,000 - $5,000) the sailor is satisfied that he has received an equivalent service value of $7,000 while the Navy has incurred only $5,000 in cost.

Figure 6 illustrates a simple savings example.

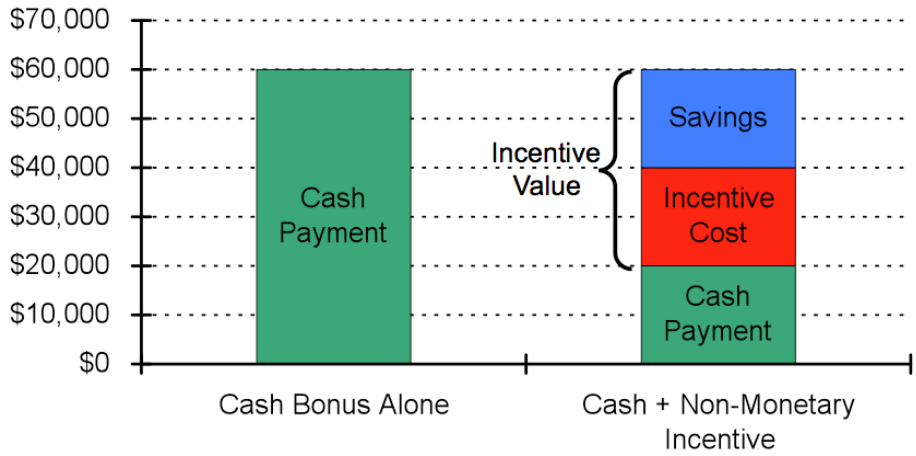

Figure 8. Example: CRAM Savings[37]

F. PROCESS

This project uses a menu style NMI solicitation method and uniform auction to determine bidder retention. The values used in this CRAM model are:

- *ISO* the salary offer from Firm B
- $NMI1_v$ is the personal value of NMI #1
- $NMI1_c$ is the Firm A cost to provide NMI #1
- $NMI2_v$ is the personal value of NMI #2
- $NMI2_c$ is the Firm A cost to provide NMI #1
- $NMIC_v$ is the personal value of receiving both NMIs in combination
- S is the bidder's salary request
- B_i is the bidder's total cost to Firm A as calculated by the formulas:
- *COV* is the B_i of the first rejected bidder.
- N is the number of bidders
- *RANK* is the rank of each player
- R_r is the retention rate

[37] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, "The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives."(Technical report, Naval Postgraduate School, 2008).

- N_r is the number of bidders to retain
- FI is the final income paid to each bidder

1. Calculations

Once bidders select any desired NMIs and enter their salary request, S, the following calculations are performed to find the total cost, B_i, of each bidder to Firm A:

- $B_i = S + (NMI1_c)$; When only NMI #1 is selected;
- $B_i = S + (NMI2_c)$; When only NMI #2 is selected; and,
- $B_i = S + (NMI1_c + NMI2_c)$; When both NMIs are selected

2. Bidder Ranking and Retention

Following calculation of each bidder's B_i, subjects are ranked from highest cost to lowest cost. The number of bidders is then counted and the retention rate is applied. The retention rate is simply a numeric value between 0 and 1. If you desire to retain all bidders, the retention rate, R, would be 1. If you choose to only retain 50%, R would be 0.5.

For the purposes of this experiment, $R = 0.5$, as we seek to mirror past research on the topic that assumed a 50% retention rate.[38]

The following calculations are performed following the ranking of bidders:

- N is counted
- Number of bidders to retain is calculated by $N_r = N * R_r$
- Retention is determined by the statements;
  - if($RANK <= N_r$) the bidder is not retained (highest B_i)
  - if($RANK > N_r$) the bidder is retained (lower B_i)
- COV is determined by identifying the first rejected bid (B_i when $RANK = N_r$)

[38] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010).

3. Earnings

All players that are not retained are paid their respective *ISO*.

- If not retained, $FI = ISO$

All players that are retained are receive a total compensation value determined by the following formulas:

- $FI = COV - (NMI1_c) + (NMI1_v)$ if only NMI #1 is selected
- $FI = COV - (NMI2_c) + (NMI2_v)$ if only NMI #2 is selected
- $FI = COV - (NMI1_c + NMI2_c) + (NMIC_v)$ if both NMIs are selected in combination.

G. CHAPTER SUMMARY

This chapter examined the different auction methods with CRAM. By examining approaches to enhance the SRB system for both the sailor and the Navy, uniform price reverse auctions seem very promising. Not only can they provide truth-revealing values from the sailor; they also ensure that the Navy fully mitigates opportunity cost in its forecasts. These reverse auctions also offer important data on the current morale within the Navy, as indicated by willingness to stay, and simultaneously optimize retention savings. Even considering that NMI values fluctuate between sailors, the Navy will never face extraneous costs for retention barring collusion within large vastly dispersed groups of sailors. By placing the onus for retention value on the individual sailor, the Navy stands to gain accurate retention numbers while maintaining the high standard of technical and leadership expertise that it cannot rely upon under the current system.*

***NOTE**: This analysis assumes the military seeks to retain those qualified service members (as determined through Perform to Serve) that are most willing to reenlist, as is consistent with current SRB policy. There are alternative auction designs that pay premium bonuses for more highly qualified service members if quality of the retained force is a more important consideration than implied by current SRB policy.[39]

[39] Christopher S. White, "The Uniform Price Quality Adjusted Discount Auction for Aviation Continuation Pay: Potential Benefits to the U.S. Marine Corps," (MBA Thesis, Naval Postgraduate School, 2010), 40.

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V. MATERIALS AND METHODS

A. MATERIALS

The experiment designed for this project required the use of computers connected via a local area network (LAN). To satisfy this requirement, reservations were made to use a computer lab containing 18 computer terminals for subjects and one server computer for the experimenters. LAN access is critical based on requirements to compare each subject's input against all other subjects. While it is technically possible to run multiple client servers on the same computer, the need for experiment controls and ease of input do not make this feasible. Instead, a single login is used for all computers in the computer lab.

Once operating under the single login, experimenters then open client servers on all computer terminals that subjects will be using. The computer program and server is run from the server terminal at the front of the classroom.

B. PERMISSIONS AND SOLICITATION

The Naval Postgraduate School Institutional Review Board (IRB) gave approval for this project experiment following completion of the online course and applicable request forms. Following approval, requests were made to secure the computer lab and an email was sent out to all students studying in the Graduate School of Business and Public Policy (GSBPP). Twelve responses were received and the participants were given instructions on date, location, time, and estimated duration.

C. ADMINISTRATION

One hour prior to the designated experiment time the computer lab was secured of all personnel with the exception of experimenters. Twelve computer terminals were activated and logged-on using a common login name and password. Client servers were opened on each of the computers in the body of the lab. This inhibited any persons from

clicking any buttons or entering any data until the instruction period began. Because the server computer being used at the front handles the data generation, no data was displayed other than a blank client screen.

D. PARTICIPANT INFORMATION

Twelve volunteers participated in the survey. The sample characteristics are shown in Figures 9–11.

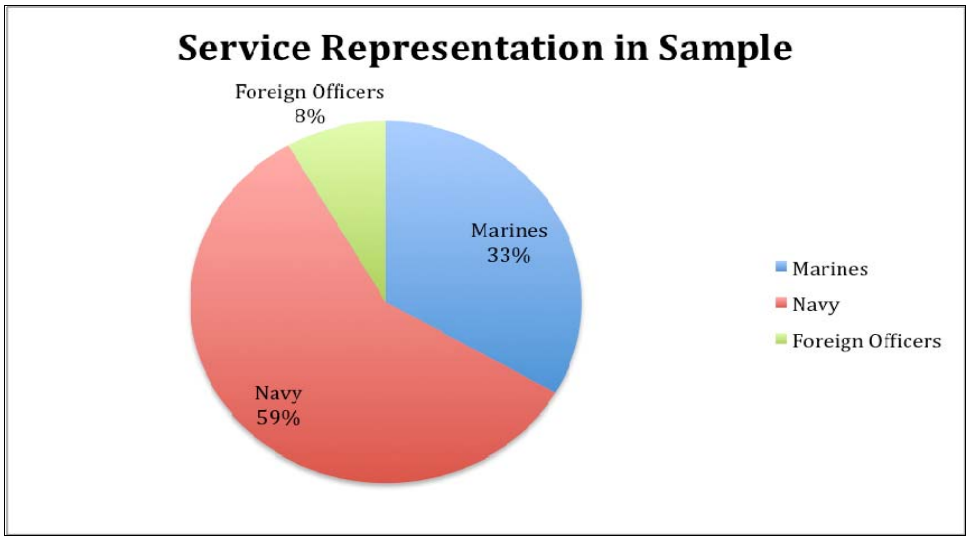

Figure 9. Service Representation in Sample

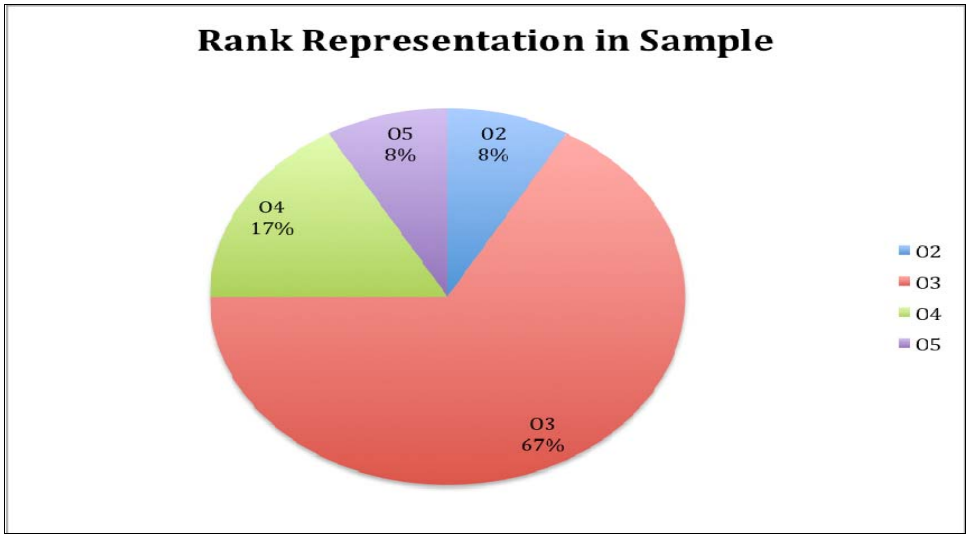

Figure 10. Rank Representation in Sample

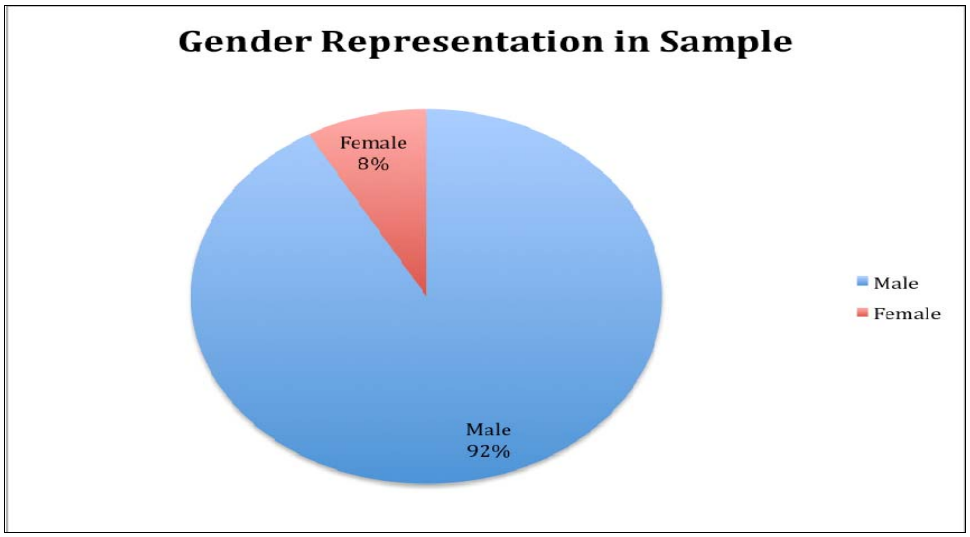

Figure 11. Gender Representation in Sample

E. PARTICIPANT INSTRUCTION

Once all equipment was verified to be in working order, the twelve participants were allowed into the classroom and placed randomly at one of the computer terminals. At that time, they filled out a consent form and partially filled in the receipt of payment they would sign following the transfer of funds at the conclusion of the experiment. Instructions identical to those being used by the experimenters were provided at each terminal. Subjects were instructed to follow along as the instructions were read aloud and to take notes if the participant felt the need.

The experimental scenario description was read to the participants they participated in a 2 round practice session identical to the subsequent 10 rounds of recorded play. The experimenters received no questions during the instruction period even though the opportunity was offered if needed. During the 2 practice rounds, participants were guided through each entry required on the input screen. Once all inputs were received, the program automatically advanced to the results stage, displaying the outcome of the round to all participants. At that time, the experimenters ensured that 50% of the subjects were retained and that no ties had taken place.*

*__NOTE__: Ties are mitigated by adding a small decimal random number to the total cost of each person. This is further described in the following chapter.

F. CONCLUSION AND PAYMENT

At the conclusion of the experiment, the total value of earnings for each participant was calculated and multiplied by an exchange rate. In this experiment, the exchange rate was 1 USD = 2.3×10^{-5} Experimental. Payouts to participants ranged from $24.75 to $31.00. Each participant signed their receipt of payment before exiting the room.

VI. EXPERIMENT DESIGN AND ADMINISTRATION

A. EXPERIMENT DESIGN

A large portion of this project research involved developing a computer program that would compare user inputs from many subjects and determine which of the subjects to retain or lay-off. Previous experimentation by Kyle Hahn and Marlow Levy involved participants placing bids and comparing them to values that were already part of a Microsoft Excel spreadsheet. Because it did not compare each subject's bid to the rest of the sample, it was hard to say how, or if, the bidding strategies would change if presented with feedback against other players.

1. Experiment Scenario

The experiment consisted of 10 rounds of play involving salary offers and combinatorial NMI play. Participants are currently working for Firm A, but have an alternative cash-only salary offer from Firm B. They are indifferent between working for Firm A and Firm B. Firm A is downsizing by laying-off 50% of its current workforce. It is offering current employees the opportunity to submit their required cash salary to continue working with Firm A and they are offered a choice of two NMIs. Firm A has publicized the cost of providing the NMI (and the employees' values are specified in the experiment); employees can request none, one or both of the NMIs offered. The cost of any requested NMI is added to the employee's cash salary request in determining the total retention cost. Firm A will retain the 50% of its current employees who request the lowest total retention cost; providing each retained employee with a compensation package with total cost equal to the first rejected salary request (e.g., a uniform-price auction with menu method NMI elicitation).

All NMIs were displayed in a menu elicitation method. The NMI combinations presented to each subject were completely random and could be sub-additive, additive, or super-additive.* This complex decision-making scenario affords the best information on how subjects react to real-time feedback. It also is the most accurate example of a

corporate scenario as firms will choose to offer NMIs to employees based on the assumption that people who value NMIs higher than company cost will cost less to retain, but will feel as if they are gaining more than simple salary alone.

*__NOTE__: Sub-additive refers to any NMI combination whose combinatorial value is less than the combined value of each NMI. Additive refers to NMI combinations whose combinatorial value is equal to the sum of the two NMI values. Super-additive refers to those NMI combinations that are greater than the additive value of the individual NMIs.

B. PROGRAM

The CRAM experiment designed for this project utilized the Zurich Toolbox for Readymade Economic Experiments (ztree). This program, developed by the University of Zurich in Switzerland, features a refined approach to interactive experiments involving many subjects. The program itself uses coding typical of visual basic and c++. However, the code is placed within separate "stages" throughout the programming window. This allows the user to define precisely which stage each calculation should take place.

The program itself captures many of the fundamental operators desired for economic experiments. During an experiment, the researchers log into required terminals under one login profile. Once all the computers have been started in this manner, the experimenters open the program code on a single computer that starts the server. A client server called a "zleaf" is opened on each participant's terminal. This displays a stagnant window until the program is started from the server terminal. Once all subjects are ready to begin, the experimenter runs the program from the server terminal and subjects see the desired output display on their screen. All inputs are then made by entering data using the keypad and clicking a "submit" button at the bottom of the page. Computations are autonomous once all subjects have input their data; results are displayed on the screen.

While the University of Zurich claims that experimenters with no programming experience can develop a program quickly, the learning curve is steep for those that have never dealt with computer languages.

1. Program Parameters

The program developed for this project utilizes the random operator function in ztree to generate values between a certain upper and lower bound. This ensures that the values presented to each subject accurately reflect various offers that may be encountered in real world bidding. The values listed below are consistent with past experiments in the CRAM concept.

- Salary offers from Firm B were randomly generated with a minimum value of $50,000 and a maximum value of $150,000.
- NMI 1 Costs to Firm A were randomly generated with a minimum value of $0 and a maximum value of $25,000.
- NMI 2 Costs to Firm A were randomly generated with a minimum value of $0 and a maximum value of $25,000.
- Personal Value of NMI 1 was a factor ranging between .25–1.25 of the NMI 1 cost for that round.
- Personal Value of NMI 2 was a factor ranging between .25–1.25 of the NMI 2 cost for that round.
- The combinatorial cost of choosing NMI 1 and NMI 2 in combination was purely additive of the NMI 1 and NMI 2 cost.
- The combinatorial value of choosing NMI 1 and NMI 2 in combination was a factor ranging from .5–1.25 of the purely additive NMI1 and NMI2 values.
- Total Cost of Each player was determined by the formula: Salary requested + Cost of selected NMIs = Bid (B_i)
- Comparison of each participant B_i was executed in the program that ranked them one through twelve.
- Players ranked 1–6 (Highest B_i) were laid off.
- Players ranking 7–12 (Lowest B_i) were retained with a total cost to Firm A for all retained equal to the first rejected bid (B_i) for whichever player ranked #6.

2. Program Code

The experimental program was coded and refined over the course of approximately eight weeks. The program's code is displayed by stage in Appendix B. Screenshots of the client displays is found in Appendix C.

C. CHAPTER SUMMARY

Chapter VI provided a brief synopsis of the programming language and coding for the experiment. It also includes a discussion of the interface and parameters used in the research. Instructions, code, and screenshots can be found in Appendices A–C.

VII. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

A. RESULTS

The experiment entailed 2 practice rounds and 10 rounds of performance play. 120 data points were obtained from the experiment. Any possibility of ties at the cutoff value was mitigated by generating a random number between 0 and 1 and adding it to each subject's total cost. During the experiment, no ties were observed at any point and data was clean and consistent. The players were able to navigate the 10 rounds of performance play in approximately 15 minutes time. This efficiency can be attributed to the program's performance and autonomous calculations and displays.

1. Bidding

All bids were analyzed independently. During each round, a total bid representing the total cost of each player to Firm A was received. The variable "B_i" represents this value. The optimal bid for each round was calculated based on the offer from Firm B and the optimal NMI selection for each player. The variable "B_i^*" represents this value.

Optimal bids are those that follow the formula:

Salary Offer from Firm B

<u>- Value of Selected NMIs</u>

Salary request to Firm A

Figure 12 shows the results of dividing the actual bids, B_i, by the optimal bids, B_i^*. Answers are in percentages relative to the optimal bid; 100% represents an optimal bid, bids less than 100% represents under-bidding relative to the optimum, bids greater than 100% represent over-bidding relative to the optimum.

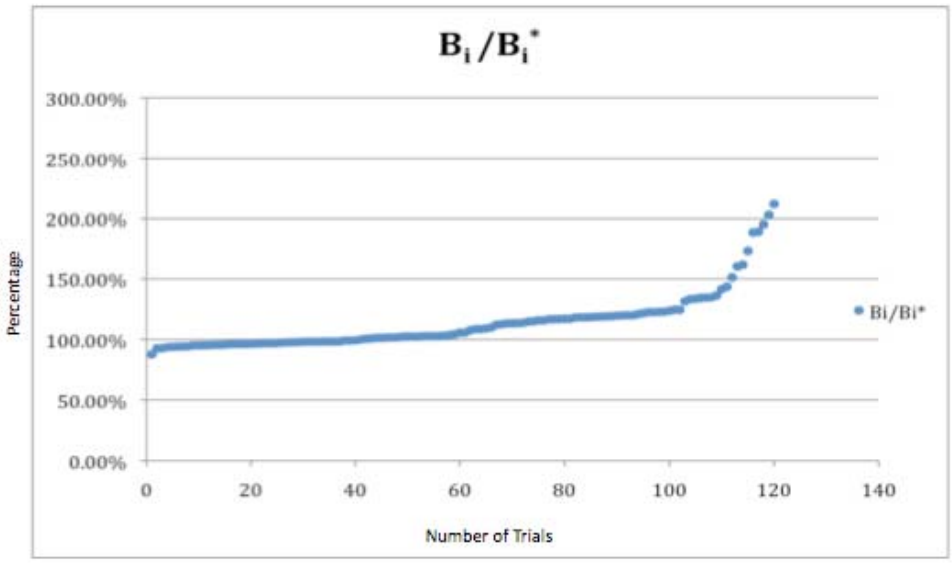

Figure 12. Actual Bid divided by Optimal Bid (Percent)

The approximately 20 bids that lie above 125% represent bids that were received on salary offers from Firm B that were below $90,000. Some salary requests were twice the initial offer before accounting for selected NMI costs, reflecting irrationality in subject strategy.

If we look at the optimal bids (B_i^*) for each subject vs the actual bids (B_i), we see that over half of the bids were above the optimal bid. This has the potential to cause Firm A to overpay for those retained. However, if the majority of subjects that bid rationally, the over bidders are at risk of being laid off and only receiving compensation from Firm B.

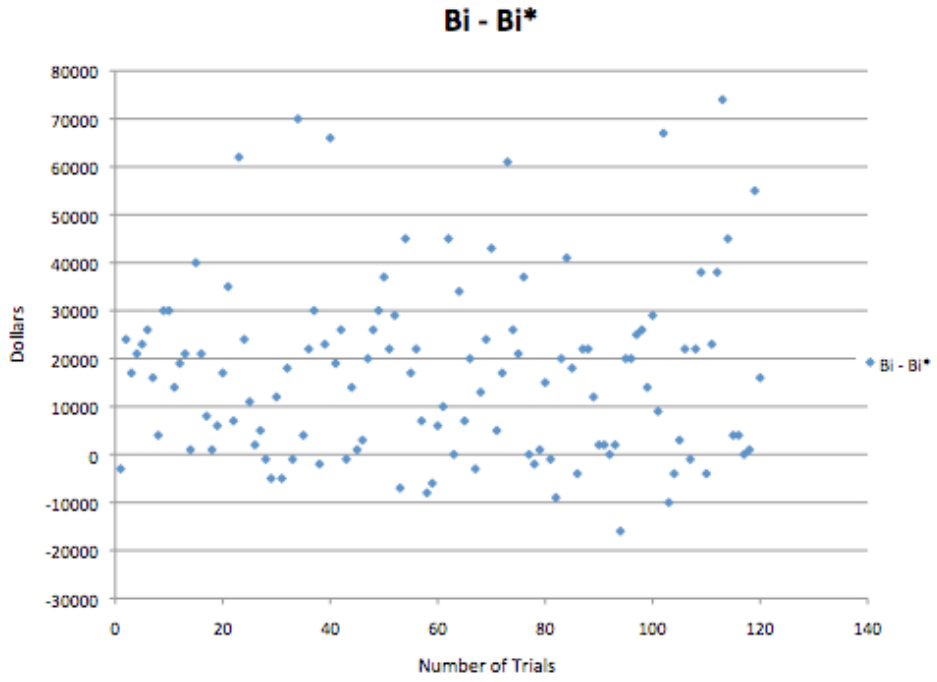

Figure 13. Difference in Bidding ($B_i - B_i^*$)

The trend lines show that on average, the bidding strategies maintained throughout the experiment inappropriately calculated reservation values and NMI values shown above. The data shows that for any given bid (B_i) the company would pay an approximate $20,000 premium to retain employees.

The average bid for all 120 trials is $16,967 above the average optimal bid with a standard deviation of $18,332. Based on statistical analysis, we can say with 95% confidence that B_i will range from $16,967 +/- $3280. It should be noted that the average standard deviation for a previous experiment was approximately 20%, whereas the experimental standard deviation here is 24%.[40]

[40] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010), 82.

2. Potential and Actual Cost Savings

The potential cost savings to the Navy is large if we use a Uniform, monetary only, auction as our reference. In this auction, only money is offered and if optimal bidding strategies are assumed, the B_i received from each subject will be the same as the salary offer from Firm B. The monetary bonus offered each retained sailor is the monetary bonus requested by the first excluded bidder (equal to their Firm B salary offer). With NMIs, all bidders should reduce their monetary bids by the value of any NMIs requested. Because they only request NMIs where the value is greater than the cost, this reduces the Navy's expected retention costs.

In Figure 14, comparing the uniform, monetary only costs to the optimal costs with NMIs shows that uniform auctions without NMIs cost more than CRAM auctions if all participants bid optimally. In this case, optimal bids, B_i^*, offer Firm A reduced cost because the Navy's cost of for NMIs is less than the personal value of the NMI.

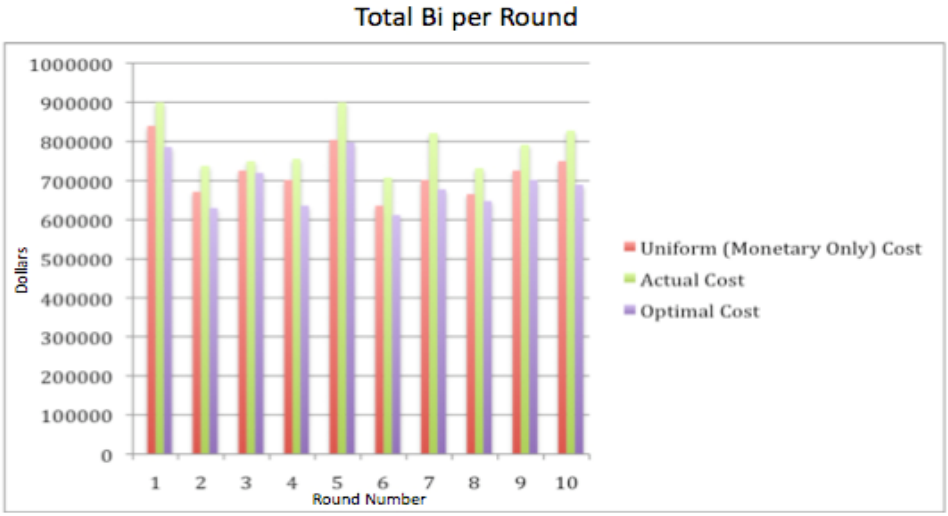

Figure 14. Total Cost to Firm A per Round

The potential cost savings using a uniform price auction with NMIs is 5% over monetary bonuses only for the 10 rounds of play, assuming optimal bids (B_i^*). However,

the actual bids (B_i) yielded a potential loss of 15% compared to the optimal outcome for 10 rounds of bidding. The results from this experiment showed a definite increase in bidding delta ($B_i - B_i^*$) from past experiments.[41]

3. NMI Analysis

Subjects were presented with three types of NMI combinations in the experiment. The first is what we term linear. For linear combinations, the value of the two NMIs in combination is purely additive. If NMI 1 is valued at $10,000 and NMI 2 is valued at $8,000, the combinatorial value would be $10,000 + $8,000 = $18,000. When presented with additive (linear) combinations, subjects chose the correct combination 71% of the time.

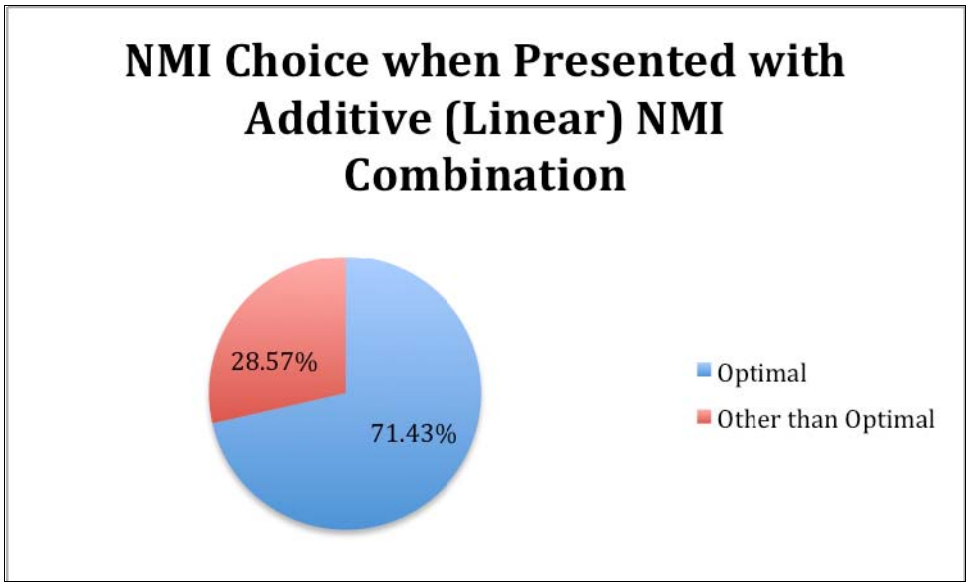

Figure 15. NMI Choice when presented with Additive Combination

Sub-additive combinations are NMI combinations that have a combined value less than the additive value of each NMI. If values for NMI 1 and NMI 2 were $10,000 and $8,000, respectively, a sub-additive combinatorial value would be anything less than

[41] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010).

$18,000. In this case, subjects might prefer to choose a single NMI if a single NMI provides them greater surplus value than the combination. In this experiment, when presented with sub-additive NMI combinations, subjects chose correctly only 58% of the time. While subjects found it more difficult to decipher the appropriate choice in sub-additive combinations, this is potentially the most difficult situation to make the correct decision if the value of both NMIs in isolation excedds the costm but the combinatorial surplus value is, at times, less than one or the other of the two singular surplus NMI values.

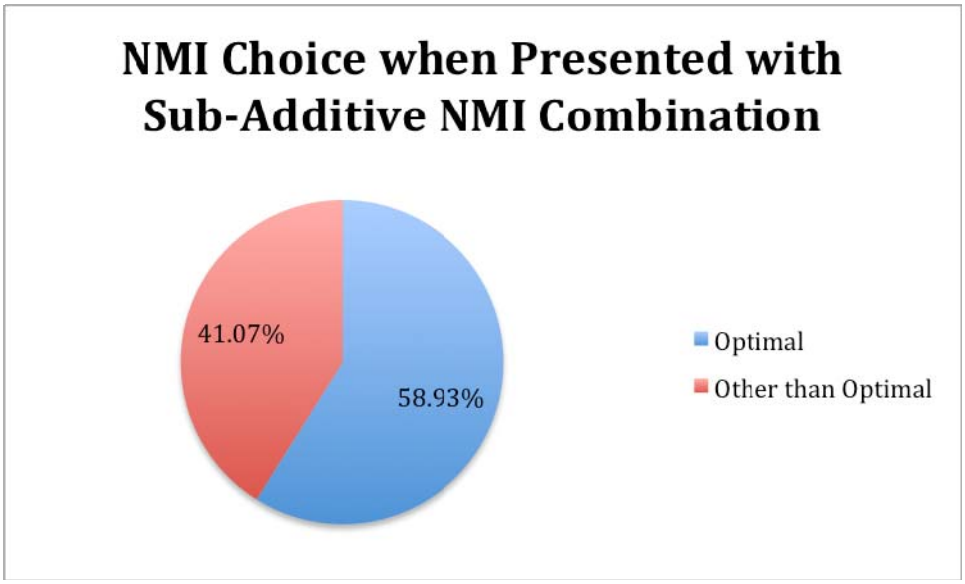

Figure 16. NMI Choice when presented with Sub-Additive Combination

Lastly, subjects dealt with super-additive NMI combinations, meaning the value of the two in combination is greater than the additive value of the two NMIs in isolation. In this case, if NMI 1 is worth $10,000 and NMI 2 is worth $8,000, the combination value must be greater than $18,000. When presented with super-additive NMI combinations, participants chose the correct combination 88% of the time.

The total percentage of correct choices for all NMI combinations was 70%, which agrees well with previous results, showing a 66% optimal choice.[42] This shows that, while participants had trouble with sub-additive values, most subjects chose correctly when presented with super-additive NMI combination.

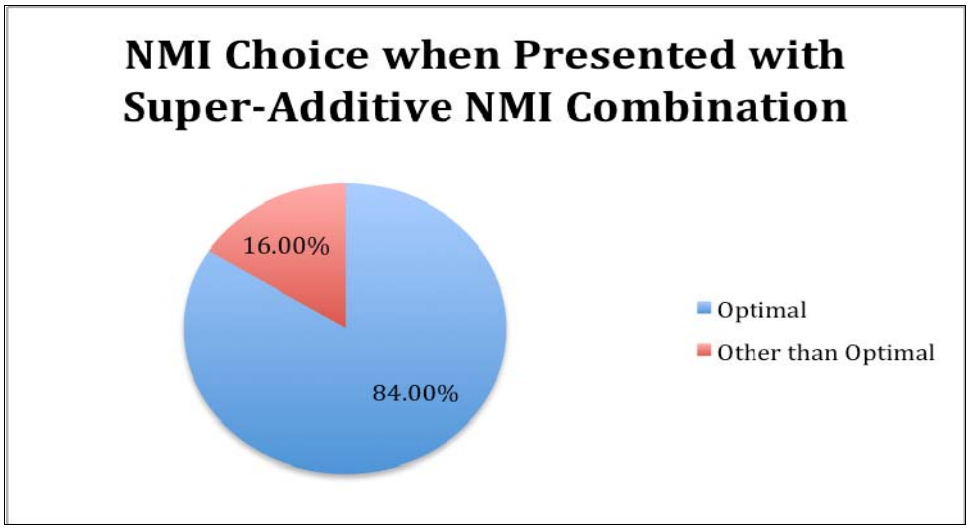

Figure 17. NMI Choice when Presented with Super-Additive Combination

B. ANSWERS TO RESEARCH QUESTIONS

1. Primary Question

What bidding strategies are adopted within a uniform-price real-time auction mechanism employing non-monetary incentives and human subject competition?

a. Answer

There are two issues when dealing with optimal bidding strategies. The first is whether the participants choose the correct NMI combinations. We noted in the NMI results that 70% of NMI choices are made correctly; the most difficult of the three scenarios was the sub-additive combination as it could require subjects to decide whether

[42] Kyle Hahn, "Investigating the Independent and Combinatorial Effects of Non-Monetary Incentives Utilizing a Uniform and Discriminatory Auction Mechanism in an Experimental Setting," (MBA Thesis, Naval Postgraduate School, 2010), 76.

an individual NMI, or the NMI combination, provided the greatest good, even in situations where both NMIs provide a positive surplus value. It should also be noted that most errors happened when the sub-additive surplus value was greater than the greatest singular NMI value, but less than the additive value. Based on the overall performance, I conclude that subjects generally chose rationally when presented with complex NMI combinations.

Secondly, we must look at the salary requested once NMIs were chosen. Clearly, the bid requests (B_i) were above the optimal bid trend. This, coupled with the fact that NMIs were generally chosen correctly, shows that most participants miscalculated their salary request. Most subjects requested salaries near Firm B's salary offer. In a uniform price monetary auction, this would be the optimal bid strategy. However, NMIs provide each employee value that must be incorporated into the salary request to Firm A.

The only systematic irrationalities witnessed in the experiment were participants that received salary offers from Firm B below $90,000. I hypothesize that they had already seen larger values, so they assumed that they should bid much higher because other participants should have higher offers. In reality, this makes little difference in a uniform price auction, as the person will be paid the salary offer from Firm B if not retained, and will receive a standard cost compensation package equal to the first excluded bid if retained. This behavior does not reflect optimal bidding in the CRAM concept; however, underlying factors such as doubt and knowledge of former bids can cloud decision making.

2. Secondary Questions

a. Does competition between human subjects alter bidding strategies as opposed to bidding against predetermined computerized values?

a. Answer

The only irrational bidding strategy was adopted when subjects were presented with values they seemed to believe were at the low end of the spectrum. At no point did we see any behavior that would suggest alteration of bid strategies compared to computerized optimal bidding competition.

I attribute this to clear instructional methods. Each subject was repeatedly told they had no preference for Firm A or Firm B and that switching jobs would not cost them any emotional, physical, or monetary stress. As a result, participants continued to bid rationally, albeit utilizing incorrect formulas.

b. Is the real-time auction viable based on alterations or consistencies in subjects' bidding strategies?

b. Answer

I believe the auction is viable for use in the Navy. Its truth revealing qualities provide a great avenue for reducing cost and precisely maintaining manpower. While any experimenter will encounter extremes in bidding strategies, the theory is still sound. However, other controls and instructions should be introduced prior to implementing a formal retention auction.

C. CONCLUSION AND RECOMMENDATION FOR FURTHER STUDY

This project expanded the understanding of bidding strategies when confronted with real-time complex decision-making. I expected that subjects would behave rationally, but was suspicious of any mental uncertainties and reservations that may cause them to bid irrationally. I anticipated that NMIs and their combinations would be chosen optimally during the majority of the experiments.

The CRAM concept is an incredibly efficient method of retention in both manpower and budget. It places the responsibility on the sailor to offer up a truthful valuation of personal willingness to serve in the U.S. Navy and mitigates costs associated

with under- or over-retention. In this time of cost cutting and force shaping, the Navy needs tools that enable them to meet their retention goals at the optimal cost.

The experiment showed consistent bidding strategies even though they did not represent optimal bidding strategies. These non-optimal bidding strategies pose new questions as to how CRAM will be administered if put into fleet use. Even so, only 6-10% of bids showed drastic departures from the bidding strategies used in this experiment, which proves CRAM can still be an effective tool for actual Navy use. CRAM benefits not only the Navy's bottom line but sailors' value as well. It certainly serves the greatest good for both parties.

1. Recommendations

I strongly recommend that any further experimentation involve a computer science graduate student in tandem with a business student. Not only will each specific expertise yield a superior product, but the experiment can be expanded to the Internet. This would allow groups of Navy personnel to participate offsite via video teleconference.

I also recommend that an experimental treatment revise the instructions to more clearly state the optimal bidding strategy. It should be clearly stated that the offer from firm B should cover the salary request to Firm A and the value of any NMIs chosen at firm A. This would hopefully elicit data closer to optimal cost and should be discussed repeatedly during the instruction session to see if experimental participants offer closer to optimal bids.

2. Further Research

I recommend performing the experiment with groups of enlisted personnel while tailoring the offers based on their current salaries and benefits. Based on the controls of the experiment, all subjects are supposed to assume no preference for their current employer, Firm A, or Firm B. We know this would not be true if actually implemented, as job security, current salary, and benefits would all play a large role in decision-making.

I also recommend that more instructional emphasis be placed on the compensation effects of a cash salary request and NMIs in combination. Even though the current instructions clearly stated that no NMIs will be received if retained by Firm B; some subjects still assumed that the cash salary request should be equal the Firm B offer and any NMIs should provide a premium over the Firm B offer.

Lastly, the distribution for salary offers should be changed from the 50k–150K currently used to 100K–199K. This should help to minimize irrational bidding by ensuring all offers are six digit amounts. I believe some of the irrational behavior exhibited in the experiment was a direct result of receiving a cash offer that was five figures vice six.

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APPENDIX A. INSTRUCTIONS

INTRODUCTION

Please do not click any buttons until instructed to do so. If you have not done so already, please fill out the participant questionnaire located at each computer. You will turn this in at the conclusion of the experiment.

The experiment in which you are participating investigates decision-making within labor markets. You will be asked to make decisions based on salary offers and non-monetary incentives (NMI).

Please listen carefully as we begin a short instructional period. The instruction period will last approximately 30 minutes and the experiment should conclude in approximately 1 hour.

This is an individual decision-making exercise and should be treated as such. It is imperative that you do not communicate with other participants in any way during the entirety of the experiment. Also, do not look on any other participants' computer screen at any time during the experiment.

SCENARIO DESCRIPTION

The experiment itself will consist of 10 rounds. The instruction period will involve going through 2 practice rounds identical to the experimental rounds. As we go through the practice round, please do not type anything or click any buttons unless instructed to do so.

1. You are 1 of __ (will be based on number of subjects) employees currently employed at Firm A.
2. Firm B is your only other potential employer.
3. You do not have any preference for Firm A or Firm B.

4. You may change employers easily at no cost or inconvenience.

5. Maximizing your annual compensation is your only goal.

6. Your compensation may consist of both monetary and non-monetary incentives.

Non-Monetary Incentives (NMIs)

A non-monetary incentive (NMI) is any compensation given to an employee other than cash.

Examples of NMIs include such benefits as:

-- Childcare,

-- Access to recreation facilities, and

-- ability to maintain geographic stability.

Firm A will submit two proposed non-monetary incentives (NMIs) to each participant. These will be generically referred to as NMI 1 and NMI 2. If you so choose, in addition to the salary provided by Firm A you may also receive:

(a) NMI 1 only.

(b) NMI 2 only.

(c) Both NMI 1 and NMI 2, or

(d) Neither NMI 1 nor NMI 2.

It is solely up to the employees retained by Firm A to choose the NMIs they wish to receive. Making the decision to select or reject an NMI will be further discussed in the next section.

Your Value for Non-Monetary Incentives

There will be three values listed for NMIs. Two will be for NMI 1 and NMI 2 alone, while one value will be a combinatorial value if both NMI 1 and NMI 2 are selected:

1. Personal Value of Receiving NMI 1 $

2. Personal Value of Receiving NMI 2 $

3. Personal Value of Receiving Both NMI 1 and NMI 2 $

These values define your personal valuation of NMI 1 and NMI 2 as well as the combination value of both NMIs together.

Effectively, each NMI value is the same as a monetary incentive of an equivalent amount. For decision purposes, you will desire to receive the NMI more than any monetary value less than the personal value of the NMI.

At the same time, you want to receive a cash amount greater than the NMI value, if available.

Please note that the value of the NMIs in combination may be less than (sub-additive) or greater than (super-additive) than simply summing the personal value of NMI 1 and NMI 2.

Total compensation with NMI is equal to:

(1) Your annual salary, plus

(2) Your value for any NMIs or combination of NMIs you receive.

Your total earnings for each period are determined by the total value of the compensation package. That is the total of your salary and the value of any NMIs received.

Salary offers and NMI values will change as we advance through each round of the experiment.

The Value of NMIs in Combination

The NMI 1 and NMI 2 combination value will not always be the same as the sum of the two NMIs (purely additive).

The value in combination may exceed the additive value of NMI 1 and NMI 2 (super additive).

Conversely, the combination value of NMI 1 and NMI 2 may be less than the additive value (sub additive).

These differences in NMI values may be used to decide which NMIs you choose.

The Distribution of NMI Values

Each employee will value NMIs differently.

Some employees will have a very low value of an NMI while another employee may value the same NMI very highly.

For both of the NMIs offered by Firm A, employee valuations will range between $0 and $25,000.

The NMI values are generated randomly throughout the range, so each employee will have a different valuation of the same NMI.

The Cost of Non-Monetary Incentives

There is a cost to Firm A provide each NMI to an employee.

NMI 1 and NMI 2 will have a distinct cost to Firm A.

1. Firm A Cost to Provide NMI 1 only $
2. Firm A Cost to Provide NMI 2 only $
3. Firm A Cost to Provide NMI 1 and NMI 2 $

Please note that the cost incurred by Firm A to provide both NMIs in combination is the sum of NMI 1 cost and NMI 2 cost.

Downsizing at Firm A

Firm A will be downsizing. 50% of its employees will face immediate layoff.

Employees will have parity in job security at both Firm A and Firm B following the layoffs.

Employment Offer from Firm B

Firm B will employ anyone who is laid off by Firm A.

You will go to work for Firm B immediately if laid off by Firm A.

Salary Offer from Firm B

A confidential salary offer to work at Firm B has been received by each employee currently working at Firm A.

This offer reflects the annual salary an employee will make if they come to work for Firm B.

All salary offers from Firm B are unique to each employee.

Salary Offer From Firm B: $

If you go to work for Firm B you will receive the salary offer alone and will not receive any non-monetary incentives.

Distribution of Salary Offers from Firm B

You will only be shown your unique salary offer from Firm B. You will not be shown any other employees salary offer from Firm B.

Firm B's salary offers are spread evenly between an upper and lower limit.

You will not be provided with the range of the salary offers from Firm B.

Each unique salary offer will lie somewhere between the upper and lower limit.

Because the salary offers are randomly generated, your offer may be higher or lower than other employees.

Determining Which Employees to Retain at Firm A

Firm A will retain 50% of employees.

Firm A will determine the level of compensation based on NMI choices and Salary request. Together, these will reflect your total cost to the corporation.

Retention will be determined by evaluating total cost based on:

1. Any NMIs the employee wishes to receive if they are chosen for retention by Firm A; and

2. The salary requested by the employee if he/she is retained by Firm A.

Firm A's calculation of total cost will be according to the following formula

(1) The total cost of any singular NMIs or NMIs in combination that are selected by the employee, plus

(2) The annual salary amount desired by the employee from Firm A in the survey.

The employees who submit the lowest 50% of cost compensation package requests will be retained by Firm A.

The employees who submit the highest 50% of cost compensation package requests will be laid off by Firm A.

Any employees laid off will immediately begin work for Firm B at the annual salary offered at the beginning of each round.

Determining Compensation for Employees at Firm A

We assume that employees will receive different levels of compensation to remain at Firm A due to different choices in NMI selection.

However, the total cost of each compensation package will be the same for each retained employee regardless of salary or NMIs requested.

Each employee will receive a package that is equivalent to the compensation request of the lowest-cost laid-off employee.

For example, we will refer to the cost of the lowest-cost laid-off employee as the "cutoff cost."

Any retained employees will have submitted compensation requests that are lower than the cutoff cost.

Any employee that is retained by Firm A will receive any NMIs that he/she requested during the survey.

Each employee retained by Firm A will receive a salary calculated by the following:

NMI(s)	Received Salary Received
None	Cutoff Cost
NMI 1	Cutoff Cost - Cost of NMI 1
NMI 2	Cutoff Cost - Cost of NMI 2
NMI 1 & NMI 2	Cutoff Cost - Cost of NMI 1 - Cost of NMI 2

All employees retained by Firm A will receive a salary equal to the cutoff cost minus the cost of any NMIs received. Because NMI cost may vary, not all retained employees will receive the same salary, but total compensation will be the same for all employees retained by Firm A.

As a result, total compensation for those retained by Firm A will not depend on:

1. His/her salary request, nor

2. The personal value of any NMIs selected.

PRACTICE ROUND – PRACTICE SALARY AND NMI SURVEY (PRACTICE ROUNDS 1&2)

You should now all be looking at a screen that displays:

1. Salary offer from Firm B.
2. Firm A cost of providing NMI 1
3. Personal Value of Receiving NMI 1
4. Firm A cost of providing NMI 2
5. Personal Value of Receiving NMI 2
6. Personal Value of Receiving NMI 1 and 2

You may refer to this instruction sheet at any time during the experiment if you need to refresh your understanding of the scenario. If you still have questions, please raise your hand and someone will be with you shortly.

Let's focus on the computer screen and begin describing entry of numerical values and selection of NMIs.

1. "Enter bid for retention" will consist of you entering your desired salary to stay at Firm A. Your response should be an integer with no decimals.
2. NMI selection will be accomplished in this manner:
    a. If you desire the NMI, you will enter a "1" in the box next to the desired NMI.
    b. If you do not desire an NMI, you will enter a "0" in the box next to that NMI.
        i. For example, if you want NMI 1 you would place a "1" in the respective box.

ii. If you do not want NMI 2, you will place a “0” in that respective box.
iii. If you desire both, you should place a “1” in BOTH NMI boxes.

READ: Your Salary Request to Firm A

Please do not type anything in the boxes or click the
“Submit” button at the bottom of the page yet. During the experimental rounds, however, you will determine the annual salary and NMIs that you would like to request from Firm A based on the information above, and you will type your request in the white boxes at the bottom of this page.

During the experimental rounds, you will also be free to click the “Submit” button whenever you are satisfied with the salary and NMI request you have entered.

DATA ENTRY PRACTICE ROUND 1

We will now begin to enter data on the screen in front of you.

For illustration purposes during this practice round,
I would like each of you to type an amount equal to (Firm B’s offer + 25,000) in the white box titled “Enter bid for retention.”

Now, please place a “0” in the white box next to the title “Do you wish to accept the first NMI?” This indicates that you desire NOT to receive NMI 1.

Now, please place a “0” in the white box next to the title “Do you wish to accept the second NMI?” This indicates that you desire NOT to receive NMI 2.

After you have done so, you may click on the “Submit” button.

Once all offers have been submitted, you will see a button in the bottom right hand corner of the screen that reads “Click to View Results.” Please click this button and advance to the results screen.

PRACTICE ROUND 1 OUTCOME

You should now all be looking at the retention screen. If you are in the lowest 50%, you are retained by Firm A.

If you have a “1” next to the title “retained” you were retained by Firm A. Your total salary is noted along with any NMIs received. The total compensation is your salary plus the value of any NMIs received.

If you have a “0” next to the title “retained” you were NOT retained by Firm A. If you were not retained, you receive NO NMIs and your salary and total compensation are equal to the Salary offer from Firm B.

Does anyone have any questions? Ok, please click the “Continue” button and advance to practice round 2.

PRACTICE ROUND 2 WITH NMIs

For illustration purposes during this practice round,
I would like each of you to type an amount equal to (Firm B’s offer + 25,000) in the white box titled “Enter bid for retention.”

Now, please place a “1” in the white box next to the title “Do you wish to accept the first NMI?” This indicates that you desire NMI 1.

Now, please place a “1” in the white box next to the title “Do you wish to accept the second NMI?” This indicates that you desire NMI 2 as well.

After you have done so, you may click on the “Submit” button with the mouse.

Again, Once all offers have been submitted, you will see a button in the bottom right hand corner of the screen that reads “Click to View Results.” Please click this button and advance to the results screen.

PRACTICE ROUND 2 OUTCOME

You should again be looking at the retention screen. If you are in the lowest 50%, you are retained by Firm A.

If you have a “1” next to the title “retained” you were retained by Firm A. Your total salary is noted along with any NMIs received. The total compensation is your salary plus the value of any NMIs received.

If you have a “0” next to the title “retained” you were NOT retained by Firm A. If you were not retained, you receive NO NMIs and your salary and total compensation are equal to the Salary offer from Firm B.

Do not hit “continue” until instructed to do so.

CONCLUSION

Before clicking the “Continue” button at the bottom of the screen to start the actual experimental rounds, are there any questions on the experiment procedure?

Once we begin, you will be free to navigate through each round whenever you are ready. The program will ensure that no participants advance to any subsequent rounds until all entries have been made. Please ensure that you have double checked all values before hitting “submit’.

You are free to click “continue” and begin the experiment. If you have any problems, please notify one of the experimenters. Good luck.

Participant Information Questionnaire _____

First Name _____

Last Name _____

Rank _____

Branch of Service _____

Number of Years in Service _____

Contact Number _____

I, (print name) _____, acknowledge that I received compensation of $_____ for my participation.

Signature: _____ Date:_____

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APPENDIX B. PROGRAM CODE

A. INPUT STAGE 1

```
//Offers will be randomly generated numbers between 50000 and 150000,
//rounded to the nearest thousand dollars
Offer = round( 50000 + random() * 100000, 1000);

//NMIs will be randomly generated numbers between 0 and 25000,
//rounded to the nearest thousand dollars

//NMI Number 1
NMI1 = round( random() * 25000, 1000);

//NMI 1 Cost to Firm A
NMI1CorCost = round( (NMI1) * (.25+ random()), 1000);

//NMI Number 2
NMI2 = round( random() * 25000, 1000);

//NMI 2 Cost to Firm A
NMI2CorCost = round( (NMI2) * (.25+ random()), 1000);

//NMI Values in Combination
NMI3 = round( (NMI1+NMI2) * (.5+(.75 * random())), 1000);
```

B. CALCULATION STAGE 1

```
//Finds total cost of each player
NMI1_Cost = if (NMI1_Rep == 1, NMI1CorCost, 0);
NMI2_Cost = if (NMI2_Rep == 1, NMI2CorCost, 0);
TCost = BIDRET + NMI1_Cost + NMI2_Cost + random();
```

C. CALCULATION STAGE 2

```
//Ranks players by Total Cost
Rank = count (same( Group ) & TCost >= :TCost);

//Counts number of players
N = count ( same (Group));
```

```
//Determines how many to retain based on percentages (this case 50%)
NRet = round(N * .5, 1);

//Determines if retained or not retained
Retain = if(Rank > NRet, 1, 0);

//Determines total value
NMI1_Val = if (NMI1_Rep == 1 & NMI2_Rep == 0, NMI1, 0);
NMI2_Val = if (NMI1_Rep == 0 & NMI2_Rep == 1, NMI2, 0);
NMI3_Val = if (NMI1_Rep == 1 & NMI2_Rep == 1, NMI3, 0);

//Return Highest Value for those retained
if(Rank == NRet) {Coff = TCost;}

//Determines NMIs received
NMI1_rec = if(Retain == 1, NMI1_Rep, 0);
NMI2_rec = if(Retain == 1, NMI2_Rep, 0);
```

D. CALCULATIONS STAGE 3

```
//Applies cutoff value to all players
MCoff = round( maximum(Coff), 1000);

//Determines Salary
Salary = if(Retain == 1, MCoff - NMI1_Cost - NMI2_Cost, Offer);

//Determines Income
Income = if(Retain == 1, MCoff + NMI1_Val + NMI2_Val + NMI3_Val, Offer);
```

APPENDIX C. EXPERIMENT SCREENS

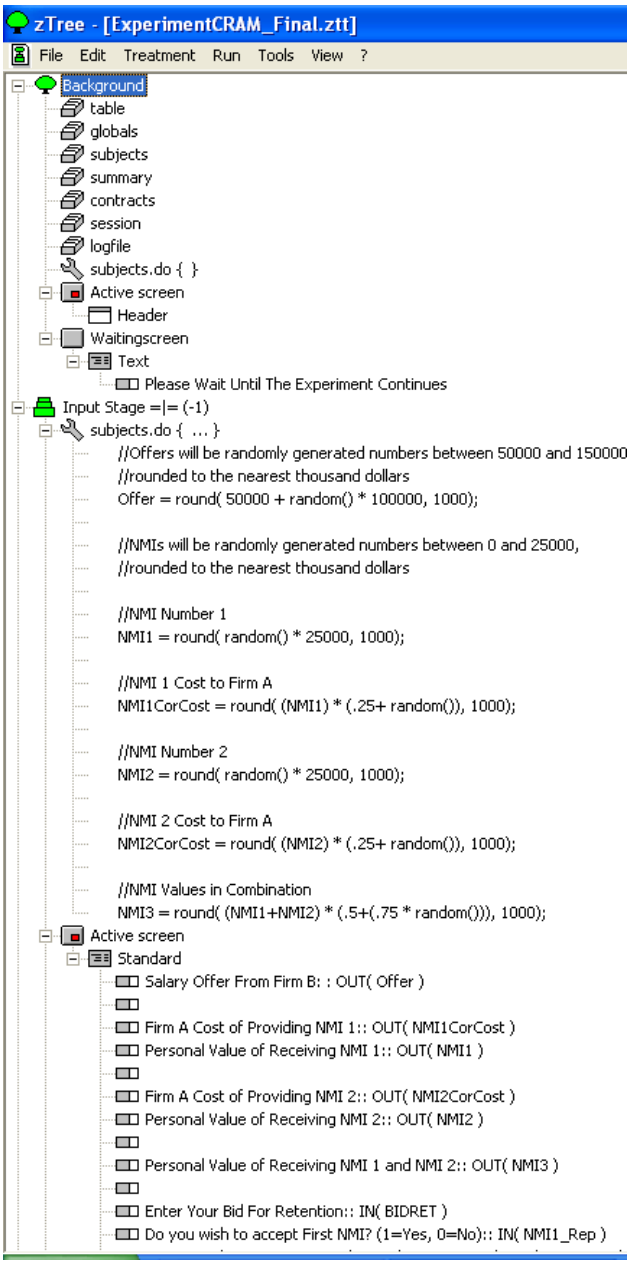

Figure 18. Programming Screen (cropped for better readability)

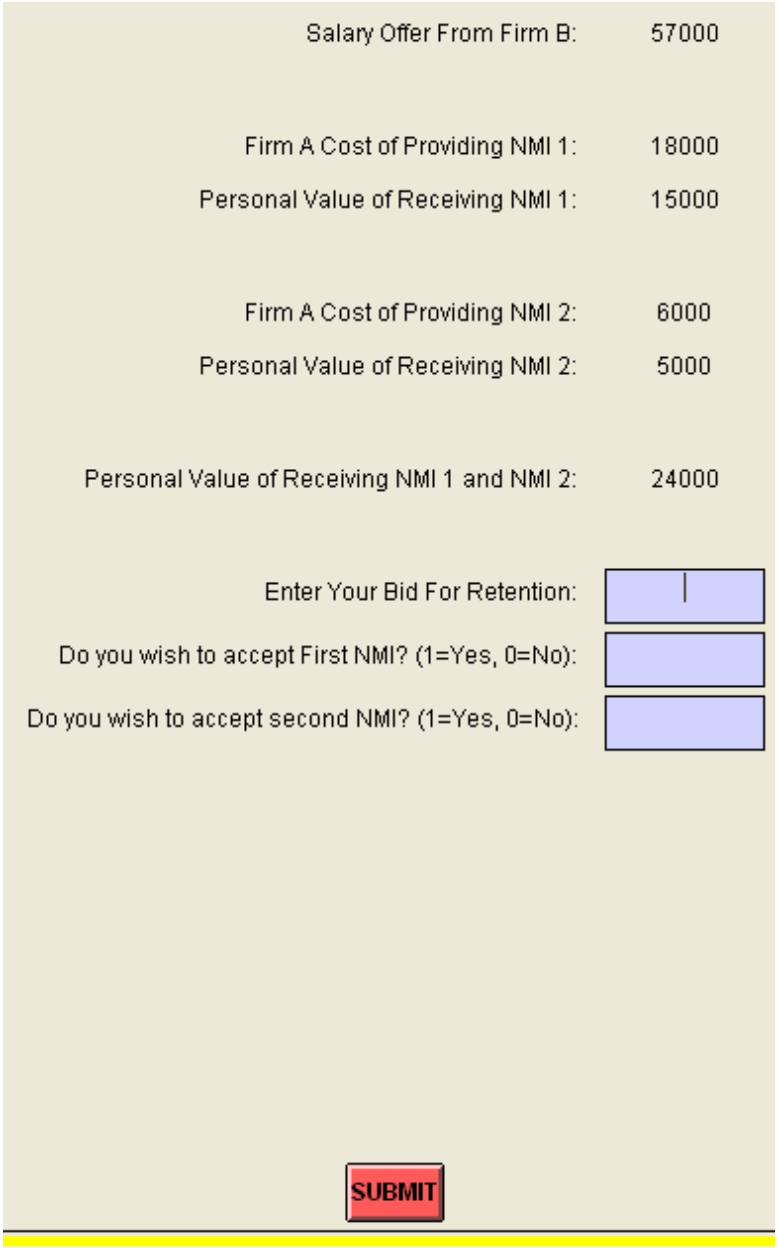

Figure 19. Initial Output Screen (cropped for better readability)

Figure 20. Retention Output Screen (cropped for better readability)

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APPENDIX D. EXPERIMENT NOTES

November 29, 2010 @ 1300:

- Started on time

- Experimenters: Joshua Tiley and Bill Gates

- 12 participants showed up for survey

- All computer terminals were functional

- Instruction period lasted 20 minutes

- All rounds were combinatorial, menu type elicitation

- Program performed with zero issues

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