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AUCTION MECHANISMS FOR ALLOCATING INDIVIDUALIZED NON-MONETARY RETENTION INCENTIVES IN COMPLEX DECISION ENVIRONMENTS: EVALUATION VIA LABORATORY EXPERIMENTATION

by

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March 2010

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Hypotheses suggested that experimental subjects would choose NMI combinations that maximize their personal compensation value and then appropriately adjust their bid to the optimal level. The experimental results of the study support the hypotheses. In all auction formats, individuals appropriately selected the optimal NMI combinations 70 percent of the time. Those choices that were considered complex were still chosen correctly 66 percent of the time, suggesting individuals do behave rationally when dealing with various combinations of NMIs. These results provide support for the practical use of such auction mechanisms for incorporating NMIs in the retention process.

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Interest in non-monetary incentives (NMIs) as a retention tool in the military services is increasing; however, prior research indicates that providing the same NMIs to all retainees is an expensive and inefficient approach. This research used an experimental methodology to investigate the use of auction mechanisms that create individualized retention bonuses combining both monetary and non-monetary incentives. Specifically, the experiment examined individuals' behavior patterns in using these auction mechanisms while including NMIs with independent and combinatorial qualities (complements and substitutes). Prior research with NMIs has assumed an additive relationship; however, this is often not the case.

Hypotheses suggested that experimental subjects would choose NMI combinations that maximize their personal compensation value and then appropriately adjust their bid to the optimal level. The experimental results of the study support the hypotheses. In all auction formats, individuals appropriately selected the optimal NMI combinations 70 percent of the time. Those choices that were considered complex were still chosen correctly 66 percent of the time, suggesting individuals do behave rationally when dealing with various combinations of NMIs. These results provide support for the practical use of such auction mechanisms for incorporating NMIs in the retention process.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACOL	Annualized Cost of Leaving
BAH	Basic Allowance for Housing
BAS	Basic Allowance for Subsistence
CNA	Center for Naval Analysis
CRAM	Combinatorial Retention Auction Mechanism
MOS(s)	Military Occupational Specialty(ies)
NMI(s)	Non-monetary Incentive(s)
NPS	Naval Postgraduate School
SRB	Service Reenlistment Bonus
U.S.	United Sates

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I. INTRODUCTION

A. PURPOSE

The Selective Reenlistment Bonus (SRB) program has proven itself to be a very influential tool. For example, the United States Marine Corps has used the SRB to shape manpower needs for many years, most recently with the 202,000 authorized end-strength increase.[1] However, the program has become increasingly expensive to employ and the current program design has significant weaknesses.

This research further investigated the use of auctions as force-shaping and force-management tools for military manpower needs. Specifically, the following research investigated the use of uniform-price and discriminatory-price auction mechanisms that incorporated monetary and non-monetary incentives (NMIs) to influence retention among military service members. An experiment was designed, conducted, and analyzed to see how individuals behave when choosing from NMI options with either independent or combinatorial valuations and how these NMIs choices influenced monetary bidding behavior.

B. GENERAL BACKGROUND

In an all-voluntary force, military services attempt to maintain authorized end-strengths by influencing and adjusting accessions and retention through compensation and incentives. With the exception of the current economic

[1] B. J. Swenson, "Manpower Increase Leads to $10,000 Re-enlistment Incentive," *Marine Forces Reserve*, (February 2007), http://www.marforres.usmc.mil/mfrnews/2007/2007.02/AIP.asp (accessed: 26 February 2010).

downturn,[2] maintaining required manpower in the United States (U.S.) military has become more challenging and expensive. Once the economy begins to realize positive growth, we can expect to see familiar manpower challenges reappear.

To fill shortages in Military Occupational Specialties (MOSs) characterized by inadequate manning, low retention, and high replacement costs, the current practice is to provide SRBs in the form of pure monetary compensation.[3] The SRB is less like a bonus and more of a wage differential provided to specific individuals whose skills are in high demand.[4] The reenlistment bonus program has become increasingly expensive and has received more attention because of dramatic spending increases. Factors that influence the SRB budget include a war on two fronts, strategic planning changes, and economic factors. Overall, the data suggests that it is becoming more expensive to retain specially qualified military personnel via the current SRB program.

There are well-known problems with the current SRB program, such as selecting which occupational specialties

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[2] Otto Kreisher, "Recession Helps Military Recruiters Reach 36-year High," *National Journal*, (October 2009), http://www.nationaljournal.com/congressdaily/cda_20091014_5927.php (accessed: 23 October 2009).

[3] U.S. Department of the Navy, Department of the Navy Fiscal Year (FY) *2010 Budget Estimates Submission, Justification of Estimates*, May 2009, Military Personnel, Marine Corps (Washington, D.C.: Government Printing Office, 2008), 57. http://www.finance.hq.navy.mil/FMB/10pres/MPMC_Justification_Book.pdf (accessed: 19 January 2010).

[4] Peter J. Coughlan, "Introduction to Auction Economics," (Lecture, Naval Postgraduate School, Monterey, CA, January 15, 2009).

to include in the SRB program,[5] precision in selecting the right amount of required reenlistments, and the cost-effectiveness of paying high economic rent based on estimated bonus amounts.[6] This research sought to provide more knowledge in ways to resolve the last two problems, precision and cost-effectiveness. The use of auction theory combined with experimental economics provides a theoretical framework showing the potential advantages of using a reenlistment bonus program based on an auction mechanism combining monetary bonuses with NMIs. The experiment is designed using the Combinatorial Retention Auction Mechanism (CRAM), which is a tool that efficiently selects the least-cost individuals to meet end-strength goals through an auction incorporating individualized combinations of NMIs.

The research used the CRAM and further investigated how individuals select various combinations of NMIs. Specifically, an experiment sought to determine the effects of NMIs with independent and/or combinatorial values while using uniform-price and discriminatory-price auction mechanisms. The ultimate goal is to implement a new reenlistment retention system that can better match the supply and demand of military manpower while saving government resources.

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[5] U.S. General Accounting Office, *GAO Highlights, Military Personnel: Management and Oversight of the Selective Reenlistment Bonus Program Needs Improvement*, Report, GAO-03-149 (Washington, D.C.: Government Printing Office, 2002), 1.

[6] Peter J. Coughlan and William R. Gates, "Auction Mechanisms For Force Management," in *Attitudes Aren't Free: Thinking Deeply about Diversity in the US Armed Forces*, ed. James E. Parco and David A. Levy (Alabama: Air University Press, 2010), 507-519.

C. RESEARCH QUESTION

The research addressed the following questions:

1. Primary Question

Do individuals understand and make reasonable decisions using the Combinatorial Retention Auction Mechanism in simulated retention scenarios?

2. Secondary Questions

a. Do individuals make rational decisions when faced with numerous NMI choices?

b. Do individuals select the optimal NMI combination when faced with a complex choice due to combinatorial values?

c. When facing discriminatory-price and uniform-price auctions, do individuals appropriately adjust their bid to the optimal value for the particular auction format?

D. SCOPE AND LIMITATIONS

This thesis includes a basic review of U.S. military compensation and the current SRB program. It also reviews prior research concerning auction theory, the CRAM, and economic experiments. An experiment conducted provides the background and necessary data to answer the research questions. This study primarily focused on improving the SRB program, while the theories discussed can likely be applied to other force-shaping/force-management tools. This thesis used NMIs in a notional sense and does not investigate specific NMIs, such as sabbaticals.

E. METHODOLOGY

This thesis is both qualitative and quantitative in nature. The focus is on further exploring different aspects of the CRAM as a reenlistment tool by reviewing prior research. A series of laboratory experiments investigated the use of independent and combinatorial NMIs with uniform and discriminatory auction mechanisms.

F. ORGANIZATION OF STUDY

This research is a continuation of an on-going investigation by Dr. Peter Coughlan and Dr. William Gates into the cost-effectiveness of offering monetary and non-monetary reenlistment retention packages, or flexible benefits packages, to military personnel. Much of the thesis builds on this prior research.

Chapter II provides an overview of military compensation and current force-shaping/force-management tools. The SRB program is discussed in-depth, explaining how it functions today. The chapter concludes by identifying weakness with the current program.

Chapter III introduces auction mechanisms and the key benefits of the CRAM. The “total rewards” concept combines monetary bonuses and NMIs into the auction process. Issues raised about NMIs, such as super/sub-additive valuations, provide the justification for an experiment.

Chapter IV explains economic experiments including design issues. Experiments are an excellent resource in order to determine potential effects of policy or program changes.

Chapter V discusses the specific experiment conducted, its design, and expected results. Chapter IV and VII presents the results of the experiment and provides conclusions and recommendations.

G. CHAPTER SUMMARY

An all-volunteer military force requires continuous monitoring. The current SRB program has significant weaknesses, and prior research has identified potential ways to fix the problems. This research is designed to shed more light on the use of auctions and NMIs as a reenlistment tool for the military services.

II. MILITARY COMPENSATION

> "There is room for innovative change in the compensation system."[7]

A. CHAPTER OVERVIEW

This chapter reviews the basics of military compensation and the tools used to shape and manage the force. Emphasis is placed on the SRB program and how it functions. The chapter concludes with the two main weaknesses of the current SRB program, and leads into Chapter III, which discusses ways to fix the weakness with an auction mechanism.

B. OVERVIEW MILITARY COMPENSATION

People join the military for a myriad of reasons; aside from propensity to service, one of the most important factors influencing enlistment and reenlistment decisions is the compensation. In 1973, the United States (U.S.) switched to an all-voluntary military force, making pay a critical component of balancing the supply and demand of qualified military labor.

> Without adequate compensation, the nation would be unable to sustain the all-volunteer force, in the size and with the skill set needed, to support the missions called for in the national security strategy.[8]

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[7] U.S. Department of Defense, Undersecretary of Defense for Personnel and Readiness, *The 10th Quadrennial Review of Military Compensation*, vol. 1, 2008 (Washington, D.C.: Government Printing Office, 2008), xxii.

[8] Ibid., xiii.

On a basic level, the primary purpose of military compensation is to support defense manpower policies that in turn support the nation's defense strategy.[9] More specifically, military compensation is used to:

1. Attract people into the services in the right numbers and with the quality required;
2. Retain in service those who are needed to meet the skill, grade, and experience requirements to fill vacancies;
3. Separate those who are no longer needed.[10]

The compensation system is complex, involving a mix of basic pay, allowances, monetary and non-monetary benefits, deferred benefits, special pays, and bonuses.

1. Basic Pay and Allowances

Basic pay makes up 60 percent of a service member's total compensation.[11] The basic pay is rigid and determined by rank and years of service, not by MOS or assignment. As individuals gain rank and/or experience, their pay increases.

Allowances include Basic Allowance for Housing (BAH) and Basic Allowance for Subsistence (BAS), which vary by location, family status, or officer/enlisted status. Basic pay and basic allowances do not allow for leaders to reward

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[9] U.S. Department of Defense, Undersecretary of Defense for Personnel and Readiness, *The 10th Quadrennial Review of Military Compensation*, vol. 1, 2008 (Washington, D.C.: Government Printing Office, 2008), 9.

[10] Ibid., 2.

[11] Ibid., 19.

deserving individuals; however, leaders may reprimand by withholding pay or reducing rank (which reduces pay and allowances as well).

2. Other Monetary and Non-Monetary Benefits

One of the largest monetary benefits provided to service members is the tax advantage gained by having BAH and BAS excluded from federal and state income taxes. This compensation varies by individuals, but it accounts for roughly 6 percent of total compensation.[12]

Non-monetary benefits generally include health care, education programs, annual leave, commissaries, exchanges, fitness facilities, and other Morale, Welfare, and Recreation facilities. There are many more non-monetary benefits and, since the incentive is not purely "cash," everyone places a different value on the benefit. Despite these different preferences, however, such non-monetary benefits are provided to all service members, regardless of how much they actually value the benefit (even if they value the benefit significant less than it costs to provide it to them). The Department of Defense has also shown interest in providing NMIs, such as sabbaticals, to influence retention decisions.[13]

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[12] U.S. Department of Defense, Undersecretary of Defense for Personnel and Readiness, *The 10th Quadrennial Review of Military Compensation*, vol. 1, 2008 (Washington, D.C.: Government Printing Office, 2008), 21.

[13] Rick Maze, "DoD plan would allow sabbaticals up to 3 years," *Navy Times*, (April 2008), http://www.navytimes.com/news/2008/03/army_sabbatical_033108w/ (accessed: 18 February 2010).

3. Deferred Benefits

Major deferred benefits are retirement payments and health care support provided to retired military personnel. While these benefits are not paid to active duty service members, they are considered when discussing military compensation. However, statistics show that less than 15 percent of the enlisted force and less than 47 percent of the officer force will become eligible for the retirement benefits.[14]

4. Special Pays and Bonuses

Special and incentive pays, including bonuses, are used to address staffing shortfalls in specific occupational areas, compensate members for hazardous or otherwise less-desirable duty assignments, and encourage attainment and retention of valuable skills.[15] Bonuses in the U.S. Military have a long history dating back to the creation of the continental army.[16] This type of pay is based on geographic location, MOS, or other circumstances.

Bonuses can be put into two groups, extended and immediate force shaping/management tools. Examples of extended tools include aviation pay, family separation pay, and hazardous duty pay; these are paid monthly to individuals who qualify for them. Immediate tools are used to meet immediate needs and are designed either to increase

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[14] U.S. Department of Defense, Undersecretary of Defense for Personnel and Readiness, *The 10th Quadrennial Review of Military Compensation*, vol. 1, 2008 (Washington, D.C.: Government Printing Office, 2008), 22.

[15] Ibid., 20.

[16] Reading Eagle, “Coats Given to Army,” Reading Pennsylvania, 29 June 1975, 55.

retention or promote voluntary separation to meet end-strength requirements. An example of an immediate tool is the SRB program, in which qualified individuals in a specific MOS receive a monetary incentive when agreeing to serve for an additional time period. The following section will provide additional context concerning the SRB program.

C. THE SRB PROGRAM (MARINE CORPS)

The use of reenlistment bonuses can be dated back at least to 1920, when reenlisted service members would receive bonuses between $126 and $252, based on experience.[17] Every major U.S. war during the past century has resulted in paying service members reenlistment bonuses. A cost-benefit analysis is conducted for each occupational specialty to determine if it is cheaper to recruit and train individuals or retain individuals who have experience. It is a delicate balance to maintain the right mix of accessions and retentions.

Over the years, the program has had different names, such as the Regular Reenlistment Bonus and the Variable Reenlistment Bonus. In 1965, it was renamed the Selective Reenlistment Bonus program. Over the years, the SRB has become the primary tool for affecting reenlistment rates, due to its flexibility, effectiveness, and option to be suspended when not needed. Additionally, the SRB can specifically target the two areas that are at risk of shortages: those technical jobs where members have skills

[17] The Delmarvia Star, "11 Young Men Here Enlist In Navy: Local Recruiting Office Finds Attractive Assignments For Them," Wilmington Delaware, 19 September 1920, 10.

highly valued in the civilian economy and therefore have better civilian alternatives, and those jobs that are arduous.[18]

The Marine Corps Order on SRBs states that:

> The SRB program was established to assist in attaining and sustaining adequate numbers of career enlisted personnel in designate MOSs and within particular years-of-service groupings. The program provides a monetary incentive for a reenlistment of at least four years at three career decision points during the first 14 years of service. Marine Corps Bulletin 7220 series, published separately and revised as required to meet the needs of the Marine Corps, identify MOSs eligible for a SRB and their multiples. The intent of this program is that Marines who receive a bonus for reenlistment in a particular skill serve the entire period of reenlistment in that skill.[19]

Not all service members are eligible; the SRB is designed to target specific individuals based on MOS and years-of-service. The bulletin referenced in the Marine Corps Order is usually issued annually, and lists the MOSs along with years-of-service zones that are available for the bonus. The SRB multiple amounts are determined by the Marine Corps with assistance from the Center for Naval Analysis (CNA). CNA uses regression analysis to predict reenlistments by MOS as a function of the SRB amount.[20]

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[18] Anita U. Hattiangadi et al., *Cost-Benefit Analysis of Lump Sum Bonuses for Zone A, Zone B, and Zone C Reenlistments: Final Report*, (Alexandria, VA: Center for Naval Analyses, 2004), 9.

[19] U.S. Marine Corps, *Marine Corps Order 7220.24M: Selective Reenlistment Bonus Program* (Washington, DC: Headquarters United States Marine Corps, 1990), 1-2.

[20] Anita U. Hattiangadi et al., *Cost-Benefit Analysis of Lump Sum Bonuses for Zone A, Zone B, and Zone C Reenlistments: Final Report*, (Alexandria, VA: Center for Naval Analyses, 2004), 64.

The bonus amount is calculated by multiplying:

- The Marine's monthly basic pay at the time of discharge or release from active duty;
- Times the number of years, and/or fraction of the years (months) of additional service for which the Marine will be obligated beyond existing obligated service;
- Times the SRB Program multiple, not to exceed 10, for the applicable MOS as designated in the current Marine Corps Bulletin 7220 series.[21]

By looking at the growth of the Marine Corps' SRB budget over the last five years, Figure 1, it is apparent that the Marine Corps placed a large value on the SRB program as a manpower tool. In fiscal year 2008, 15,737 Marines received a reenlistment bonus for a total cost of $452,000,000.[22] It was a major influential tool in the 202,000 authorized plus-up. Due to a successful SRB program and the unforeseen economic downturn of 2008 and 2009, the Marine Corps was able to meet end strength goals two years early, causing a suspension of reenlistment

[21] U.S. Marine Corps, Marine Corps Order 7220.24M: Selective Reenlistment Bonus Program (Washington D.C.: Headquarters United States Marine Corps, 1990).

[22] U.S. Department of the Navy, Department of the Navy Fiscal Year (FY) 2010 Budget Estimates Submission, Justification of Estimates, May 2009, Military Personnel, Marine Corps (Washington, D.C.: Government Printing Office, 2008). http://www.finance.hq.navy.mil/FMB/10pres/MPMC_Justification_Book.pdf (accessed: 19 January 2010).

bonuses.[23] However, once the economy begins to grow the usual MOS specific manpower shortages may become visible again. Also, the SRB program is the largest discretionary item in the Marine Corps' manpower account and, therefore, it is an easy target for cuts when shortfalls occur.[24]

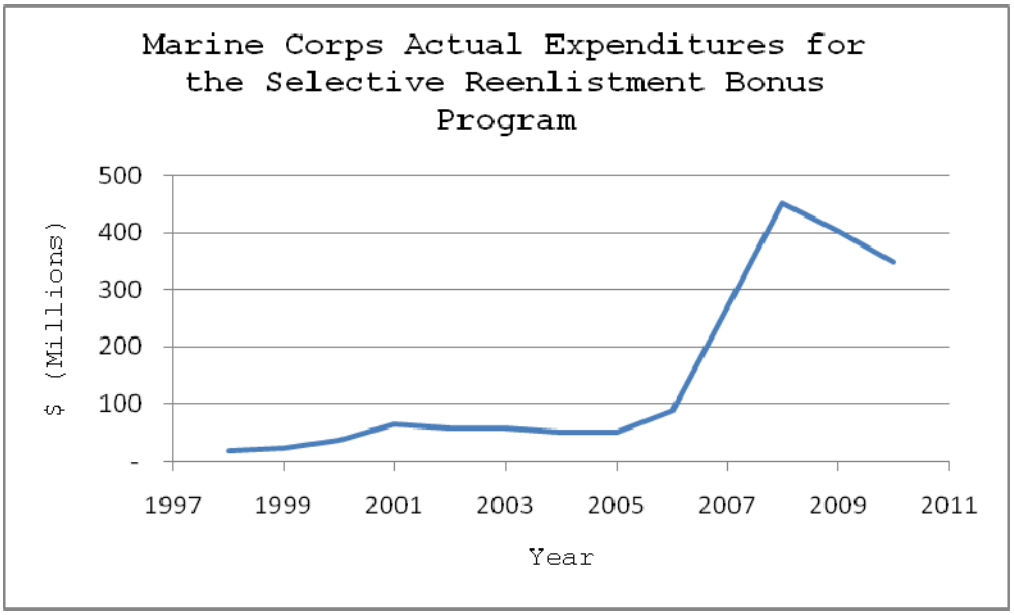

Figure 1. U.S. Marine Corps SRB Expenditures, 1998-2010 (U.S. Department of the Navy, Department of the Navy Fiscal Year (FY) 2010 Budget Estimates Submission, Justification of Estimates, May 2009, Military Personnel, Marine Corps)

1. Weaknesses

While the SRB is selective by MOS and years-of-service, it is important to note that it is equally available to all qualified Marines regardless of their

[23] U.S. Marine Corps Bulletin 7220, Fiscal Year 2010 (FY10) Selective Reenlistment Bonus (SRB) Program and FY10 Broken Service SRB (BSSRB) Program, MARADMIN 0378/09, 24 June 2009.

[24] Anita U. Hattiangadi et al., *Cost-Benefit Analysis of Lump Sum Bonuses for Zone A, Zone B, and Zone C Reenlistments: Final Report*, (Alexandria, VA: Center for Naval Analyses, 2004), 10.

intent or willingness to reenlist. Marines who are eligible to reenlist generally fall into one of three groups:

1. Marines who would be willing to reenlist for only a fraction of the SRB amount, or none at all;
2. Marines who would be willing to reenlist for the exact SRB amount;
3. Marines who would be willing to reenlist, but only for an amount that is higher than the SRB being offered.[25]

Marines who are eligible for the SRB will almost exclusively come from group 1, shown in Figure 2, and will receive a larger bonus than what was required to retain the individual.[26] This excess distribution of resources, money in this case, is also known as economic rent. It is in the best interest of the Marine Corps to obtain the required manpower needed by accurately setting the bonus amount while paying as little economic rent as possible.

[25] Paul B. Bock, "The Sequential Self-Selection Auction Mechanism for Selective Reenlistment Bonuses: Potential Cost Savings to the U.S. Marine Corps," (Master's thesis, Naval Postgraduate School, 2007), 9.

[26] Ibid., 9.

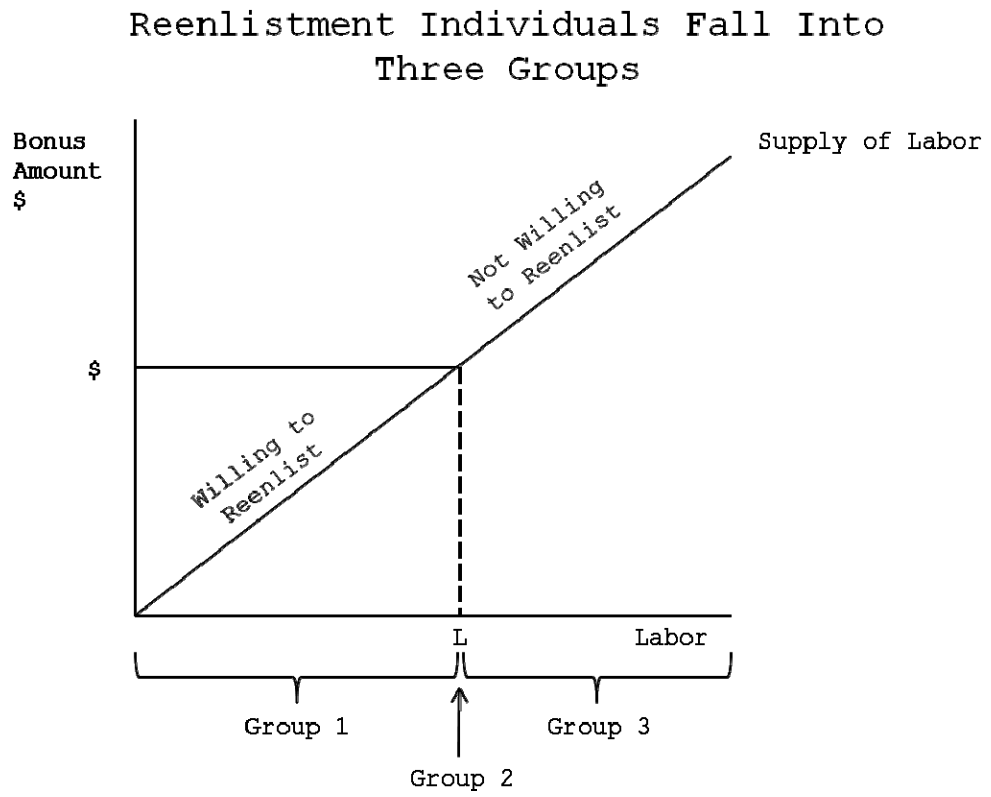

Figure 2. Reenlistment Individuals Fall Into Three Groups

One of the main drawbacks of the current SRB program is that the military services cannot identify those who would have reenlisted without the bonus or with a much smaller bonus.[27] Although the SRB attempts to be as accurate as possible, it likely over estimates the cost of retaining the required number of individuals in a specific MOS. The supply of labor can only be estimated; for this reason, setting the most economically efficient bonus amount is difficult.

As shown in Figure 3, if the goal is to have L number of people reenlist and the bonus is set at 40k, then only L'

[27] Michael L. Hansen and Martha Koopman, *Military Compensation Reform in the Department of the Navy,* (Alexandria, VA: Center for Naval Analyses, 2005), 29.

would be willing to reenlist at that amount, resulting in a manpower shortage in a required specialty. The exact shortage would be L – L'. On the other hand, if an SRB amount is too high, e.g., 60k as shown in Figure 3, the military will be able to retain all the required manpower in a specific MOS, point L, and it would have to reject individuals because L'' would be willing to reenlist. Additionally, setting a higher SRB amount results in higher economic rent, which is depicted as the shaded area labeled A. All the individuals in the shaded area would have reenlisted for 50k or less; however, since the SRB was set at 60k, everyone received 10k (60k - 50k = 10k) more than required. It is unlikely that statistical analysis or any other non-market approach will be sufficiently accurate to consistently determine the market-clearing SRB level.[28]

[28] Peter J. Coughlan and William R. Gates, "Auction Mechanisms For Force Management," in *Attitudes Aren't Free: Thinking Deeply about Diversity in the US Armed Forces*, ed. James E. Parco and David A. Levy (Alabama: Air University Press, 2010), 510.

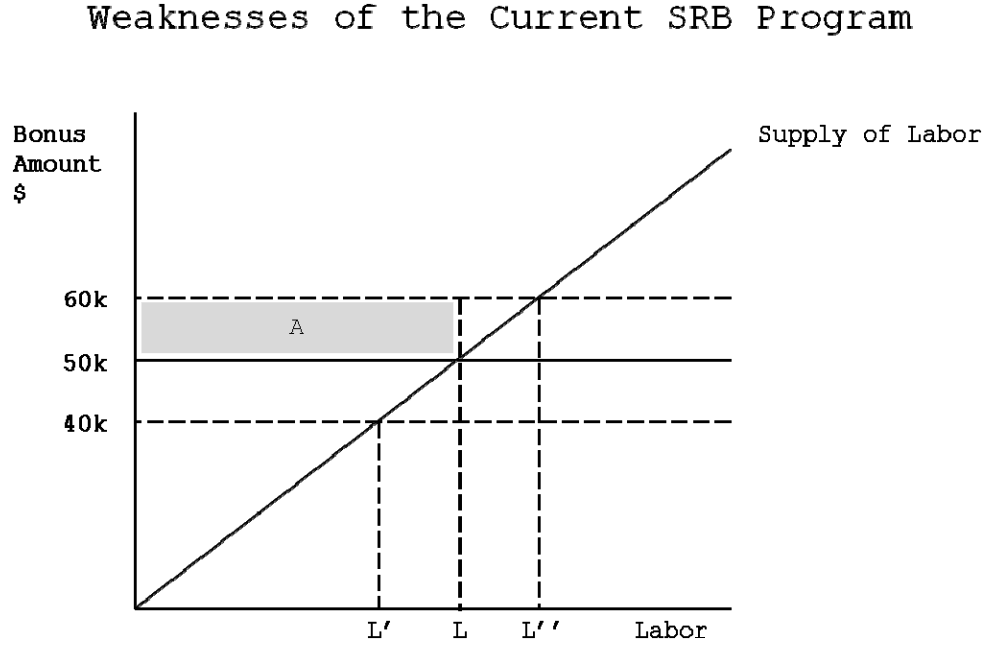

Figure 3. Weaknesses of the Current SRB Program

Another weakness of the SRB program is that all Marines in the qualifying MOS are eligible for the bonus, regardless of their willingness or propensity to reenlist. Even if the exact bonus amount could be estimated, and the exact numbers of reenlistments were met, everyone would get the same bonus that was required to attract the very last person. The shaded area in Figure 4 identifies the additional income transfers, known as economic rent, provided to all service members. Only the individual at L receives the exact amount required to elicit a decision to reenlist. Person X would have reenlisted for 20k; however, that service member receives an additional 30k.

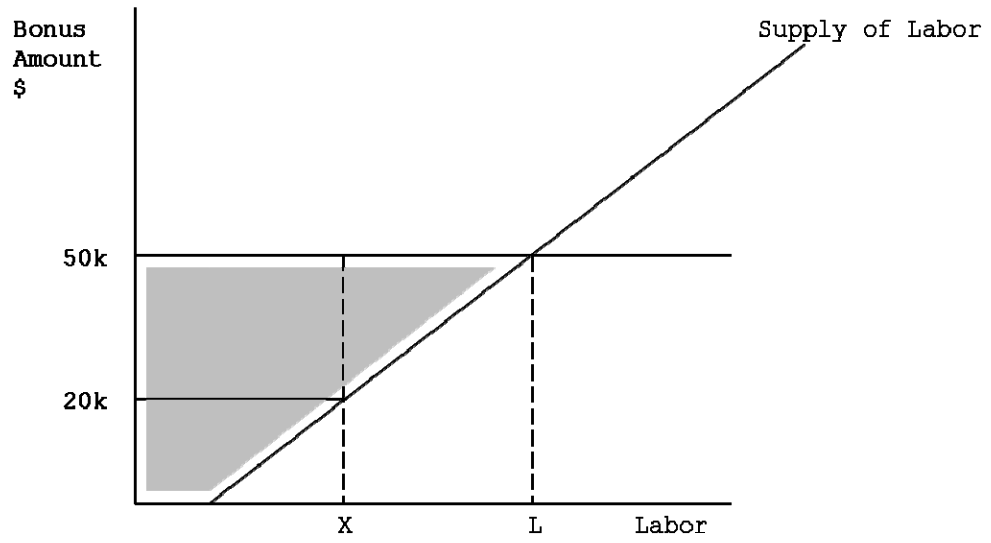

Figure 4. Uniform Distribution of the SRB Program

These two well-known issues can be identified as a precision problem and a cost-effectiveness problem.

- Precision – determining the appropriate incentive to precisely achieve the targeted end-strength goal.
- Cost-effectiveness – the associated "surplus" income transfers from the military to service members when the same incentive is provided to all retained service members.[29]

Much research has been done on the potential for using auctions to determine an individual's reservation wage, thereby identifying the exact amount required by an individual to stay in the military. By knowing individuals' reservation wages, the military would know the exact cost of retaining an exact number of individuals.

[29] Peter J. Coughlan and William R. Gates, "Auction Mechanisms For Force Management," in *Attitudes Aren't Free: Thinking Deeply about Diversity in the US Armed Forces*, ed. James E. Parco and David A. Levy (Alabama: Air University Press, 2010), 519.

Building on the concept of auctions, NMIs can be used in support of monetary incentives, thus creating combinatorial auctions for military manpower. Such auctions are considered "combinatorial" because they involve eliciting bids for (or choices among) (a) various combinations of NMIs as well as (b) the combination of NMIs with traditional monetary incentives. Prior research with the U.S. Navy has shown that individuals place a high value on the ability to select NMIs that they value. Not only do service members place a value on individually selected NMIs, research has shown that such a method would be very cost effective if implemented.[30]

D. CHAPTER SUMMARY

The military compensation system is a critical component in maintaining an all-volunteer force. It is composed of a complex mix of basic pay, monetary and non-monetary allowances, special pays, and bonuses. These tools are used to manage and shape the force as required.

The SRB is one tool that is used to meet short-term needs by influencing individuals in specific MOSs to reenlist for a given period of time in return for a monetary incentive. Over the years, this method has become increasingly expensive and has known problems concerning precision and cost-effectiveness.

[30] Brook M. Zimmerman, "Integrating Monetary and Non-Monetary Reenlistment Incentives Utilizing the Combinatorial Retention Auction Mechanism (CRAM)," (Master's thesis, Naval Postgraduate School, 2008), 127.

Prior research postulates that combinatorial auctions can be used in the reenlistment bonus program, which would seek to improve the two main problems of precision and cost-effectiveness.

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III. AUCTION MECHANISMS

> "The services should explore other pays, such as reenlistment bonuses, which could potentially use an auction mechanism to incorporate member preferences into payment rates."[31]
>
> - *10th Quadrennial Review of Military Compensation*

A. CHAPTER OVERVIEW

This chapter explains and describes the use of auctions in the military labor market. It discusses the first- and second-price auction mechanisms and how including combinations of NMIs can decrease cost to the military services while increasing the total value given to individual service members. The literature promotes the second-price sealed-bid reverse auction because of its truth-revealing design. The first-price auction lacks important qualities but it also deserves attention. Much of this chapter is based on prior thesis work and summarizes the main points.

B. WHAT IS AN AUCTION?

"Auctions ask and answer the most fundamental questions in economics: who should get the goods and at what price?"[32] The auction variation is determined by number of buyers and sellers, the environment, and the ultimate objective. Auctions can be used by a single

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[31] U.S. Department of Defense, Undersecretary of Defense for Personnel and Readiness, The 10th Quadrennial Review of Military Compensation, vol. 1, 2008 (Washington, D.C.: Government Printing Office, 2008), 13.

[32] Peter Cramton, Yoav Shomham, and Richard Steinberg, *Combinatorial Auctions*, (Cambridge, MA: MIT Press, 2006), l-2.

seller to sell goods when faced with many potential buyers (standard or forward auction) or by a single buyer to buy goods when faced with many potential sellers (reverse auction). Auctions often are used in the marketplace to buy and sell material goods; however, auctions seldom are used in the labor market to buy and sell individual labor services. In the military labor market, the military is a single buyer facing many individuals who are the potential sellers; the military wants to buy labor.

C. AUCTION DESIGNS

1. English Auction

An English auction is the most well-known type of auction. It is used for real estate, motor vehicles, and goods online via Web sites like eBay where there is a single seller and multiple buyers (bidders). The English auction consists of interactions and competition among the bidders. The price generally starts low when someone submits the first bid for the good; then other potential buyers increase their bids, agreeing to a higher price. The price of the item increases incrementally until no one else is willing to raise the bid. The last bidding person then receives the item for the price he or she stated. The most important aspect of the English auction is that all potential buyers know the current bids as the auction progresses.

2. Dutch Auction

The Dutch auction is similar to the English auction in the sense that all the bidders are present (physically or virtually) at the auction at the same time. Rather than

starting low, however, the price starts very high and then the auctioneer decreases the price gradually until one bidder agrees to the price. There is only one bid in a Dutch auction, it is awarded to the first person who calls out or otherwise announces his or her willingness to pay the current price. Unlike the English auction, in which all the bidders could observe bids from the other bidders, the Dutch auction only reveals one bid; that of the highest willing bidder. The bidders want to maximize their gain, but they need to speculate what competing buyers would be willing to pay.

3. Sealed-Bid Auctions

The open English and Dutch auctions present a problem for military labor markets because all the bidders need to simultaneously be present, or online, throughout the bidding process. This is unrealistic with military personnel operating worldwide. However, a sealed-bid auction offers a solution. Bids can be submitted over a period of weeks or months; the simultaneous physical or virtual presence of the bidders is not required. Similar to the Dutch auction, bidders have no way of knowing how other competitors value the items. Additionally, a bidder does not have the opportunity to increase or decrease their bid once it is submitted.

There are two main types of sealed-bid auctions:

a. First-Price

This is a common form of the sealed-bid auction. Bidders submit sealed bids; once all the bids are collected, the winner is the person who submitted the

highest bid, paying the value of their bid for the item. Competitors have no way of changing their bid once submitted or knowing what other competitors have bid. Bidders attempt to maximize their gain while still receiving the item; this means that an individual's bid is influenced by expectations of what bids may be submitted by other bidders. The optimal bidding strategy is to bid below the true maximum price the bidder is willing to pay, creating individual gain but increasing the risk of losing the auction. The first-price auction forces bidders to guess what others are bidding, resulting in potentially inefficient outcomes if bidders have different expectations (and thus use different bidding strategies).[33]

b. Second-Price

In a second-price sealed-bid auction, also known as a Vickrey auction, the winner with the highest bid pays an amount equal to the first-highest rejected bid. For example, if the winning bidder bids $20 and the highest losing bid is $17, the winner pays $17. Instead of paying the clearing price, the winner just pays the opportunity cost for the good.[34] This auction format has a truth revealing nature, meaning that the optimal bidding strategy is to bid one's true value for a product or service. This is the critical difference between a first- and second-price auction. This auction mechanism is less widely used; however, it is very similar to the first-price auction, the

[33] Lawrence M. Ausubel and Paul Milgrom, *Combinatorial Auctions*, ed. Peter Cramton, Yoav Shomham, and Richard Steinberg, (Cambridge, MA: MIT Press, 2006), 80.

[34] Ibid., 19.

highest valued bidder receives the item but pays a price equal to the second highest value.

The 2009 CRAM Technical Report provides a more detailed explanation about auction theory and the truth-revealing nature of the second-price sealed-bid auction.[35]

D. USING AUCTIONS FOR MILITARY LABOR

The previous section presented different auction designs and explained that the first-price sealed-bid auction and the second-price sealed-bid auctions are applicable for military labor markets. This section will explain in more detail on how both mechanisms work. Before doing so, it is important to understand an individual's reservation value.

1. Reservation Value

The reservation value is the minimum compensation for which, if given by the military, the person would continue their military service. A person's reservation value is generally estimated internally using the same concept as the Annualized Cost of Leaving (ACOL) model. The ACOL approach models an individual's decision to stay or leave the military based on the monetary differences between military and civilian employment. Monetary differences are the primary interest in the model, but there is also a variable that incorporates an individual's "taste" or

[35] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, "The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives," (Techincal report, Naval Postgraduate School, 2009), 14.

preference for military versus civilian life.[36] As described, every person has a different reservation value; it is individually calculated by evaluating civilian employment opportunities and one's taste for the military lifestyle. Someone who likes the military lifestyle might be willing to receive $10,000 less annually than for equivalent work in the civilian sector. Someone who dislikes the military lifestyle might be prepared to leave even though the military was paying $15,000 more than what he or she could receive in the civilian market.

2. First-Price (or Discriminatory-Price) Auction

When applying the first-price auction approach to the market for military labor, the winners (those whose bids were accepted and therefore are employed by the military) would be paid the value of their bids.

Figure 5 is an example of how a first-price auction would work in this context. All 30 service members would submit their bonus requests; assume for the moment that service members submit bids equal to their reservation values, an assumption relaxed below. The military service would then rank the requested bonus amounts based on cost. If only 20 services members were required, then person 20 would receive $10,000 and person 10 would get $5,000 to reenlist for a predetermined amount of time. Persons 21–30 would not be offered a bonus and they would have to find employment elsewhere. Note that each individual who was selected for reenlistment and paid a bonus receives a

[36] John T. Warner and Matthew S. Goldberg, "The Influence of Non-Pecuniary Factors on Labor Supply: The Case of Navy Enlisted Personnel," *Review of Economics and Statistics*, vol. 66, 1984, 27.

different amount, ranging from $10,000 to 0. For this reason, this variation of the first-price auction approach, in which there are multiple winners who each contract at a different price (not the first price), is known as a discriminatory price auction.[37] Total cost to retain the 20 services members is approximately $100,000 (20 * 10,000 * 0.5 = 100,000).

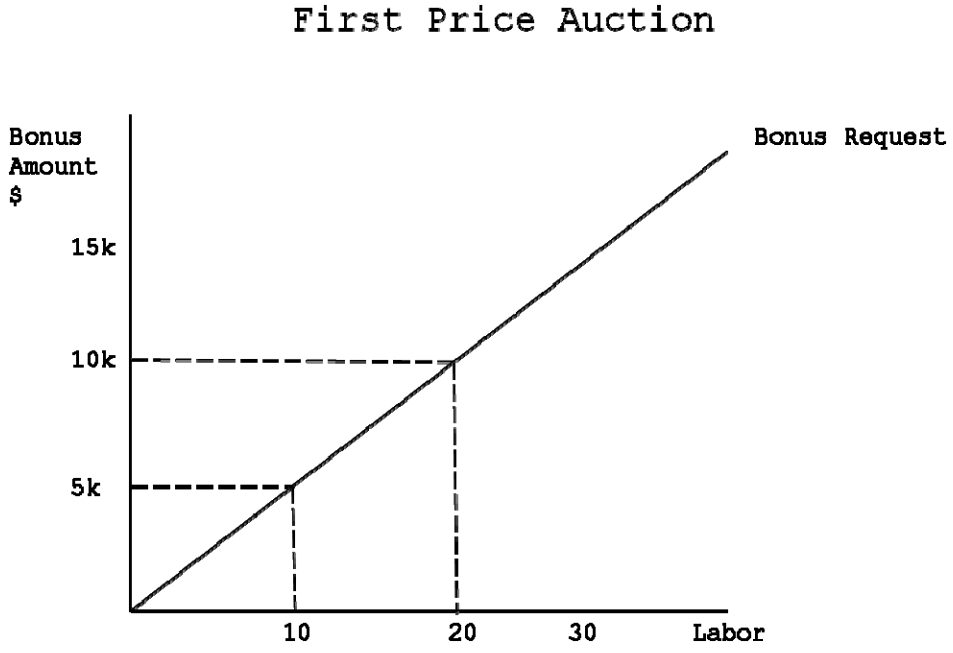

Figure 5. First-Price Auction Example

At first glance this auction appears to be efficient because the employer is not over compensating those willing to stay for lesser amounts. However, the optimal strategy in the discriminatory-price auction is not to bid one's reservation value as assumed above, but to instead bid somewhat above this amount. It is in the best interest of each individual to estimate what others are bidding and

[37] In economics, "price discrimination" refers to the practice of charging (or receiving) difference prices from different individuals.

then try to bid just below the expected cutoff (the amount of the lowest losing bid). This allows an individual to win the auction while maximizing their surplus. Also, individual's bids will be highly influenced by their level of risk tolerance.

Figure 6 presents the same scenario; however, it has individuals attempting to bid optimally. Each person is trying to bid right below what they expect the cutoff bid amount to be. The military services still retain 20 members, however, at a much different cost. In reality it costs approximately $200,000 (20 * 5,000 + 20 * 10,000 * 0.5 = 200,000) shown by the shaded sections. The darker shaded triangle shows the cost if everyone bid their true value. Appendix A provides additional information on the calculations for determining the expected profit-maximizing bid. Other variables that could affect the optimal bid include the relative risk tolerance for each individual and the information provided to the bidders. Those who were more risk averse would underbid relative to those who were less risk averse. This auction mechanism would systematically retain those people who are most willing to remain in service, while also making those who are more risk-averse somewhat more likely to be retained (given similar reservation values). The amount of information provided to bidders is also critical in decision making. If bidders were told how many people were going to be retained they would bid differently than if they had no knowledge, depending on whether they over- or under-estimated the number retained and their risk tolerance.

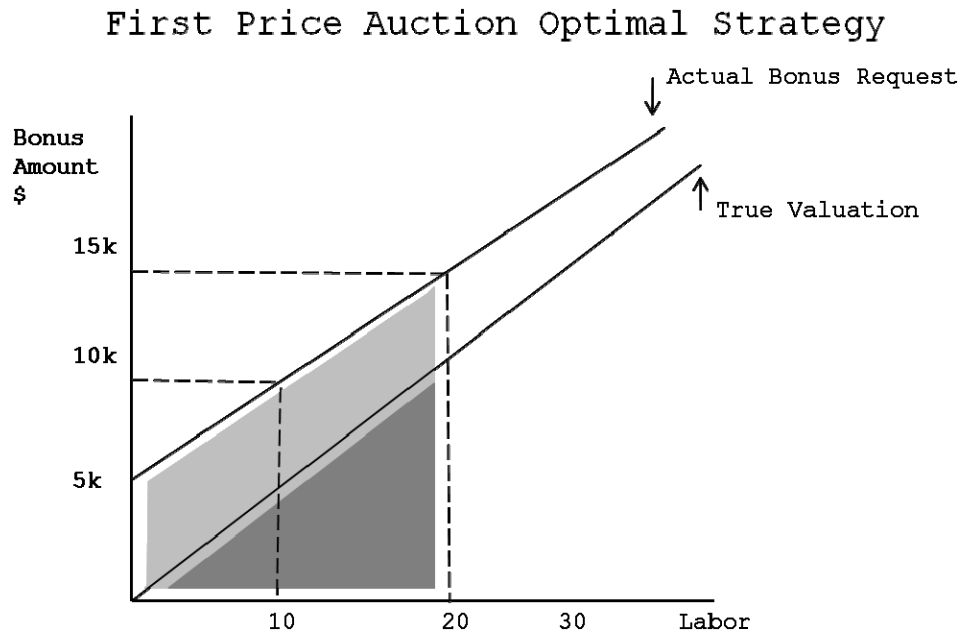

Figure 6. First-Price Auction Optimal Strategy

Another issue which should not be ignored is that each service member receives a different bonus payment among the same MOS. The discriminatory-price auction mechanism creates unequal compensation and may result in morale issues and tension within the operating forces because of pay inequality.

3. Second-Price (or Uniform-Price) Auction

When using a second-price auction approach in military labor markets, the winning bidders would all be paid the first highest rejected bid. In other words, each person who was retained would be paid the same amount.

Figure 7 shows an example of a second-price auction in this context. Individuals 1-30 submitted bonus requests and the military service only needed 20 individuals. The first highest rejected bid is the 21st person, their bid is near 10k. Persons 21–30 are not retained because they were

over the cutoff. Persons 1–20 are all paid 10k, resulting in a total cost of approximately $200,000 (20 * 10,000 = 200,000). Note that retained service members are not actually paid the second-price in this example but are instead paid the 21st-price (i.e. the 21st lowest bid). More generally, when the second-price auction approach is generalized to allow for some number N winners, the winning bidders will all pay or receive the (N+1)st price. Because all winners pay or receive the same amount, the multiple-winner format of the second-price auction is known as a uniform-price auction.

Figure 7. Second-Price Auction Example

Recall that in the first-price auction the total cost was calculated to be $200,000 as well. Both the first and second-price auctions result in the same number of retained personnel and are revenue (or cost) equivalent under certain reasonable conditions. However, in a second-price

auction it is optimal for individuals to bid their true valuation, also known as truth revealing.

E. DISCRIMINATORY OR UNIFORM?

Initially, the discriminatory-price auction appears to be the most cost effective because the military avoids paying economic rent, meaning money savings. However, that presumes that bidders do not bid optimally. There may be a learning effect for bidders. At first individuals might underbid but begin to bid optimally once they figure out the optimal strategy. Also, service members of the same MOS who received the bonus would get paid different amounts. This inefficiency might cause morale problems and resentment among the fighting force. Additionally, the discriminatory-price auction is somewhat biased toward risk-averse individuals. Lastly, the discriminatory and uniform auction mechanisms are revenue or cost equivalent in theory, as shown by Figures 6 and 7 and further supported by Appendix A.

For these reasons, the uniform-price auction has many advantages over the discriminatory-price auction. Additionally, the uniform-price auction has the benefit of being truth revealing. The truth revealing nature of the uniform-price auction allows services to actually track individual's opportunity costs. An individual who bids a high reservation value suggests that he/she has profitable civilian opportunities or a lower proclivity for military service. Those individuals that bid lower suggest that they are better off in the military service. Data gathered

could be used to evaluate how service members value their employment and be used to forecast future manpower costs. [38]

In review, both auctions select the required number of individuals at the lowest cost, yet they both have very different characteristics. The discriminatory-price auction might be cheaper in the short-run if individuals do not initially bid optimally; in the long run, however, both the uniform- and discriminatory-price auctions are revenue equivalent. The uniform-price auction provides many advantages that make it better, such as equal payments, independent of risk preferences, and truth revealing.

F. MONETARY RETENTION INCENTIVES

Chapter II discussed military compensation and showed that it consists primarily of monetary compensation. In 2007, research conducted at the Naval Postgraduate School (NPS) by Constance M. Denmond and others explained that pure monetary incentives are inadequate for addressing many reasons why service members decide to leave the military.[39] The research was directed toward Naval Surface Warfare Officers; however, the reasons for individuals departing military service can be related to the USMC and most MOSs. The research gave support for using NMIs as retention tools.

[38] Benjamin M. Cook, "Using a Second-Price Auction to Set Military Retention Bonus Levels: An Application to the Australian Army," (Master's thesis, Naval Postgraduate School, 2008), 37.

[39] Constance M. Denmond et al., "Combinatorial Auction Theory Applied to the Selection of Surface Warfare Incentives," (MBA professional report, Naval Postgraduate School, 2007), 69.

G. NON-MONETARY RETENTION INCENTIVES

The Tenth Quadrennial Review provides support for the use of individually selected NMIs. The following excerpt explains how flexible benefits could encourage reenlistment and retention.

> Equally important is the need to offer greater choice for the service member when such choice is consistent with the mission requirements. When member preferences for type of assignments, where they are stationed, or frequency and duration of deployments are consistent with the operational requirements, the compensation system should offer appropriate incentives to support such choice. Flexible benefit arrangements offer another mechanism to introduce choice for the member. And providing service members with adequate compensation encourages reenlistment, and potentially, enlistment decisions. The ultimate payoff is in member satisfaction, which in turn positive impact volunteerism.[40]

As previously mentioned, research has shown that money is often not the main force influencing individuals' decisions to stay in the military; NMIs can serve as powerful retention tools. Examples of NMIs may include homeport choice, geographic stability, and sabbaticals. By combining cash bonuses with NMIs, individuals have the opportunity to get more utility through highly valued NMIs while still receiving a monetary incentive. The military services have the opportunity to save money by providing NMIs and decreasing overall monetary payouts. A tool used to incorporate monetary and NMIs into auctions to maximize value for individual service members while minimizing cost

[40] U.S. Department of Defense, Undersecretary of Defense for Personnel and Readiness, The 10th Quadrennial Review of Military Compensation, vol. 1, 2008 (Washington, D.C.: Government Printing Office, 2008), xxi.

to the military service is known as the Combinatorial Retention Auction Mechanism (CRAM). CRAM establishes individualized incentive packages for services members that reflect their personal preferences between money and different NMIs.

H. VALUING COMBINATIONS OF NON-MONETARY INCENTIVES

Any retention mechanism which attempts to tradeoff a monetary incentive for multiple non-monetary incentives must recognize that NMIs are often valued differently depending on what other NMIs are provided in combination. Much of the research thus far which has investigated various aspects of monetary incentives and NMIs has assumed a consistent independent additive effect for the value of NMIs. In other words, it has generally been assumed that the value of any combination of NMIs is simply equal to the sum of the "stand-alone" values for those NMIs. In reality; however, this is not the likely case most of the time. Combining two NMIs that are complementary generates a combined value that is super-additive (or greater than the sum of the individual values). On the other hand, combining two NMIs that are substitutes may create a combined value that is sub-additive, or less than the sum of the individual NMI values.[41]

1. Additive

Prior research has assumed a perfectly independent additive relationship when combining NMIs. While this is

[41] Jason B. Ellis, "Variability of Valuation of Non-Monetary Incentives: Motivating and Implementing the Combinatorial Retention Auction Mechanism," (Master's thesis, Naval Postgraduate School, 2009), 44.

possible, it is unlikely that an individual's value for a NMI stays constant as it is combined with other NMIs. Figure 8 presents an example of additive NMIs.

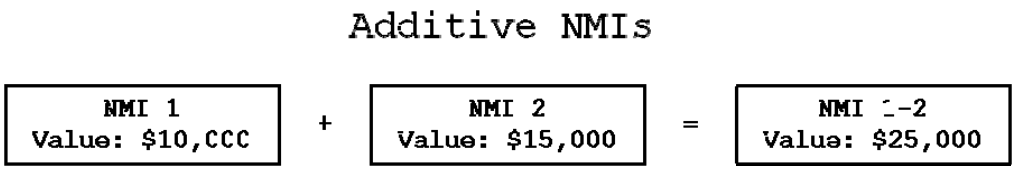

Figure 8. Additive NMIs

2. Super-Additive

Suppose an individual values geographic stability for three tours at $15,000 and homeport of choice at $10,000; it has been assumed that combining them would result in an individual value for the two NMIs at $25,000 ($15,000 + $10,000 = $25,000). In reality, the individual may place a very high value on that combination of NMIs, hypothetically $40,000. The reason for the value increase can only be speculated, but may include spouse's work stability and/or children staying longer in a specific school district. Therefore, depending on the cost to the military services, much value can be created by combining synergistic NMIs. Figure 9 presents an example of super-additive NMIs.

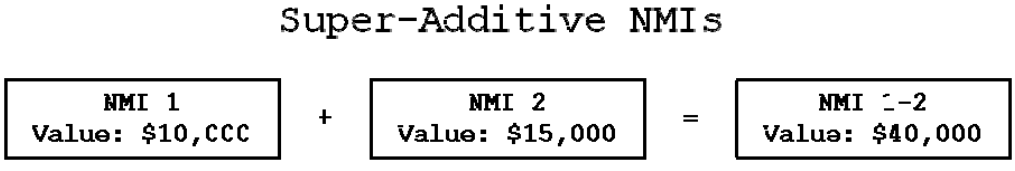

Figure 9. Super-Additive NMIs

3. Sub-Additive

Just as NMIs can become more valuable in combination, they can also become less valuable. For example, an

individual may value homeport of choice at $15,000 and telecommuting at $8,000. In combination, these may become valued at $17,000. Again, reasons for sub-additive effects can only be speculated. One scenario might suggest minimal commuting cost and inconvenience in the homeport of choice reducing the value of working remotely. Figure 10 presents an example of sub-additive NMIs.

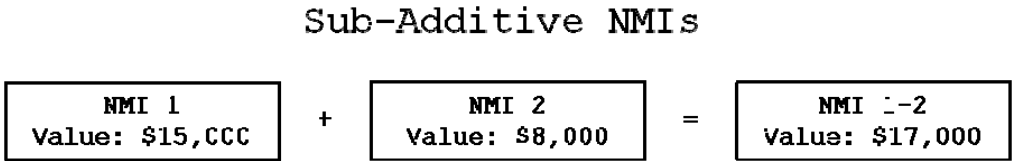

Figure 10. Sub-Additive NMIs

I. DO INDIVIDUALS MAKE RATIONAL DECISIONS?

Do individuals make rational decisions when evaluating and combining NMIs utilizing the CRAM method? NPS research conducted in 2009 determined, for the most part, that individuals make rational choices when introducing NMIs.[42] However, the previous researchers purposely assumed a perfectly additive relationship when combining NMIs to focus their study. This thesis builds on that research by investigating how individuals respond to non-additive values for various combinations of NMIs.

J. THE COMBINATORIAL RETENTION AUCTION MECHANISM (CRAM)

The Combinatorial Retention Auction Mechanism (CRAM) includes three elements, each serving a specific purpose.

[42] 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), 35.

1. An NMI allocation process which lowers the cost to retain any service members who value NMIs more than the dollar cost to provide those NMIs;
2. A combinatorial auction mechanism which provides individualized incentive packages with no "wasted" incentives;
3. A monetary auction component which automatically and endogenously sets monetary retention incentives at the absolute minimum cost necessary to achieve specific end-strength targets.[43]

1. NMI Allocation: Cost vs. Value

CRAM is designed such that service members should only receive an NMI if he/she values it more than it costs to provide. Therefore, all potential NMIs are offered to eligible service members and, if an individual places a higher value on the incentive than it costs to provide, that individual should receive it. In other words, CRAM is designed such that, for any given NMI, only service members who would rather receive the NMI than a cash amount equal to the NMI cost end up receiving that NMI. This ensures that the individual gains value and the military service reduces cost simultaneously. The value gain and cost saved depends on how much value the individual receives from a particular NMI relative to its cost.

Figure 11 provides a visual representation of the different values a target community might assign to a particular NMI relative to the cost of that NMI. The horizontal line in the diagram depicts the unit cost of the hypothetical NMI while the downward-sloping diagonal line

[43] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, “The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives,” (Techincal report, Naval Postgraduate School, 2009), 78.

depicts the demand for that NMI which is given by the varying values assigned to the NMI among the service members targeted for retention.

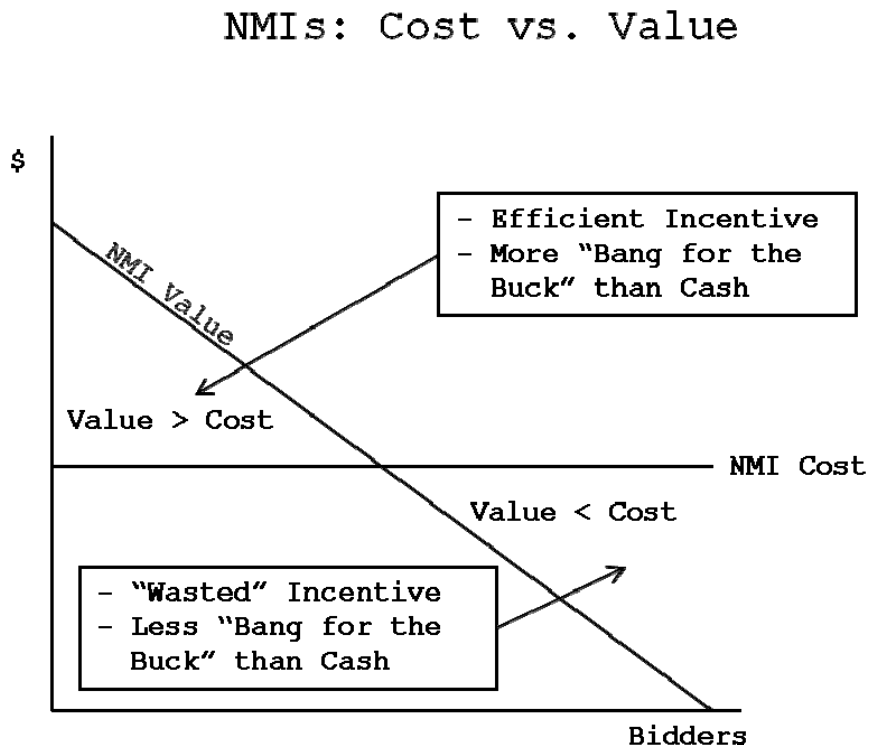

Figure 11. NMIs: Cost vs. Value (From Coughlan and Gates, 2007)

Note that, in Figure 11, value can be gained (and cost saved) by providing the NMI to those individuals who value it more than cost (those who are represented in the upper part of the demand curve). Providing the NMI to these individuals is a stronger retention incentive than providing a cash amount equivalent to the unit cost of the NMI. Hence, it is a win-win outcome to provide the NMI to those individuals.

Conversely, providing the NMI to those individuals who value it less than cost (those who are represented in the

lower part of the demand curve) is a lose-lose outcome. Providing the NMI to these individuals is a weaker retention incentive than providing a cash amount equivalent to the unit cost of the NMI. CRAM is consequently designed to only provide any particular NMI to those service members who value it more than cost.

2. Individualized Incentive Packages

CRAM creates an individualized monetary and NMI package for each service member. The optimal incentive package would include NMIs that are of high value to the individual but low cost to the government. By the selection of NMIs that are valued greater than cost, both parties can be better off.

Figure 12 presents an example of how various NMIs might have different costs to the military and how different bidders might value the NMIs. Theoretically, geographic stability and homeport choice offers value greater than cost for most individuals, while sabbatical and telecommuting appear to cost the military more in relation to most people’s value for the NMIs. For these reasons it is not beneficial to provide NMIs “universally” to all service member;, however, CRAM allows the military services to offer all NMIs to service members (even those that are only highly valued by a small population) knowing that each NMI will only be allocated to those individuals who value it more than cost. Offering all NMIs, but only providing each NMI to individuals who value it more than cost ensures that there are no “wasted” NMIs.

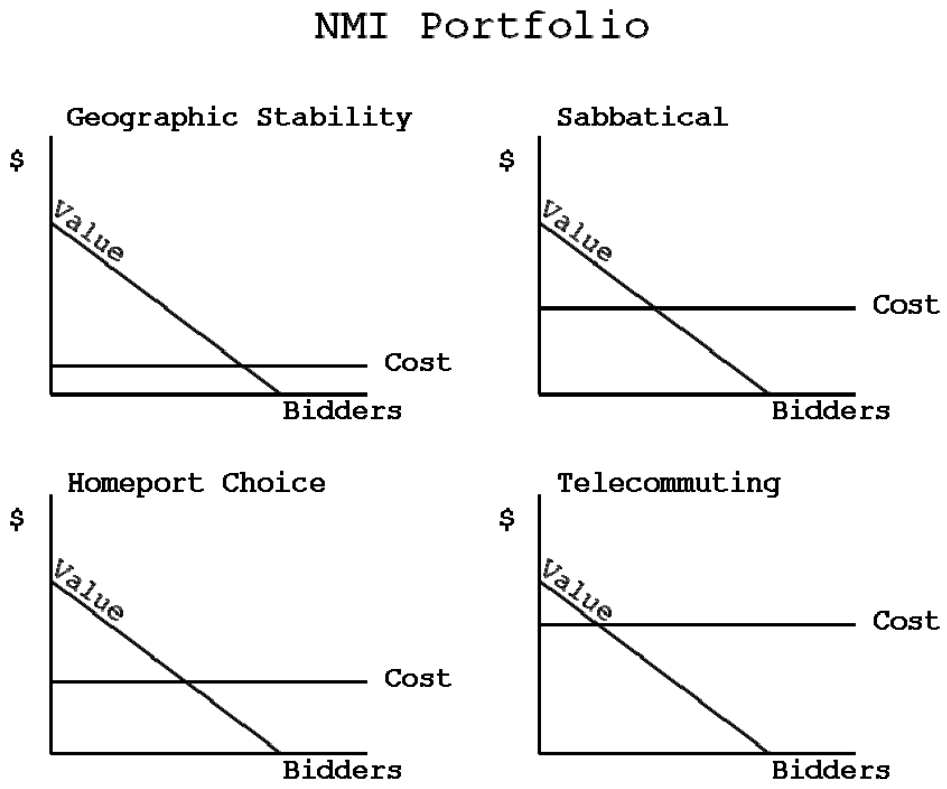

Figure 12. NMI Portfolio (From Coughlan and Gates, 2007)

3. Monetary Auction: Setting a Precise Cash Bonus

In addition to the allocation of non-monetary incentives, the CRAM mechanism also incorporates a monetary auction in which eligible service members submit a sealed-bid reflecting the monetary incentive they would require to commit to a further service obligation. Whereas SRB bonuses and other cash retention incentives have traditionally been set using statistical analysis or rules-of-thumb, the monetary auction component of CRAM endogenously and automatically (without the need for any economic or statistical analysis) determines the most cost-effective cash bonus amount (or amounts, as described

below) which will allow the military service to precisely meet its end-strength goal for the particular cohort or specialty.

K. CRAM VARIATIONS AND PROCESS

In order to understand exactly how the Combinatorial Retention Auction Mechanism actually works, it is important to first explain the four primary variations of CRAM, as each variation will operate somewhat differently. The four variations of CRAM are illustrated in Figure 13 and are classified based on two dimensions: (1) The NMI allocation method and (2) the price determination rule.

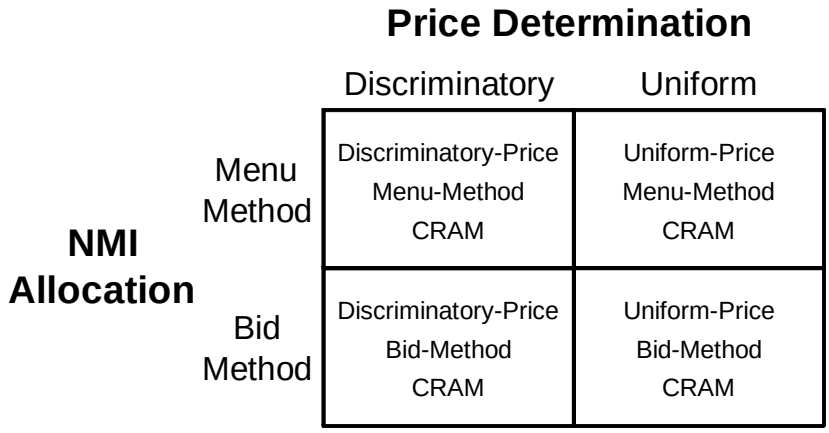

Figure 13. CRAM Variations

1. NMI Allocation: Menu-Method vs. Bid-Method

Under CRAM, NMIs can be allocated in one of two ways: The menu-method or the bid-method. Under the menu-method, eligible service members are presented all the available NMIs, along with their associated costs to provide. Service members then select from this "menu" of NMIs, knowing that they will receive any NMI selected if retained, but also that the military service will include in his/her cost to retain (see below) the combined cost of

all NMIs selected. The service member can select no NMIs, one NMI, all NMIs, or any combination of available NMIs. Each service member does best by determining which combination of NMIs hold the greatest value relative to cost.

It is also important to note that, under the menu-method, a service member's bid for a monetary retention incentive reflects the cash amount he/she would require in addition to any NMIs selected. Thus, the monetary bids submitted under the menu-method are "post-NMI" cash incentive bids.

Under variations of CRAM using the bid-method, service members submit individual bids for each NMI offered, with the bid amounts reflecting the amount of cash bonus he/she would be willing to give up in exchange for each particular NMI (if retained). Service-members are not provided any costs associated with the NMIs under the bid-method; however, they will receive any NMI for which they submit a bid greater than cost if they are retained. As with the menu-method, the military service will include in his/her cost to retain (see below) the combined cost of all NMIs allocated to him/her.

Unlike the menu-method, under the bid-method, a service member's bid for a monetary retention incentive reflects the cash amount he/she would require without any NMIs being allocated. This is necessary because, without knowing NMI costs, the service-member does not know at the time of bidding which NMIs he/she will be allocated. The service-member's combined bids for all NMIs allocated are subtracted from this "cash-only" monetary bid to determine

the “post-NMI” cash incentive bid which is used to determine each service-member’s total retention cost (see below).

The primary advantage of menu-method CRAM is that it readily accommodates the combinatorial NMI values as described previously. The service member, who presumably has some idea of his/her value of the various combinations of NMIs, incorporates these combinatorial values into his or her selection of the package of NMIs whose combined value exceeds the combined cost by the greatest amount (this is the optimal choice). The primary disadvantage of the menu-method CRAM, on the other hand, is that a reasonable estimate of the cost of providing each NMI must be known and published in advance, which can be particularly problematic for those NMIs whose cost depends on the number of service members who choose that particular NMI (such as geographic stability, homeport of choice, billet of choice, etc.).

The bid-method advantages and disadvantages are the mirror image of the menu-method advantage and disadvantages. Unlike the menu-method CRAM, the bid-method does not incorporate combinatorial NMI values effectively, unless service members are asked to submit separate bids for each possible combination of NMIs. To request bids on all combinations; however, can quickly become unwieldy. For example, with 10 NMIs available, there are 1023 different NMI combinations on which service members would have to bid. The primary advantage of the bid-method; however, is that the cost of each NMI does not necessarily need to be known in advance. In particular, after

eliciting the NMI bids, decision-makers can estimate the demand curve for each NMI (the number of service-members whose bid is higher than each possible price or cost point) and then determine the "market-clearing" price (where the cost curve intersects the demand curve).

2. Determining Winners: Total Retention Cost

After receiving all NMI selections or bids and all monetary incentive bids, the military service calculates the total retention cost for each service member. This cost is given by:

Total Retention Cost = "Post-NMI" Cash Incentive Bid + Total Cost of Allocated NMIs

The military service will then retain the set of lowest-total-cost service members. For example, if end-strength goals dictate that 2,000 service-members from a particular specialty in a particular grade must be retained in a particular year, then the military service will retain the 2,000 service-members among this group whose total retention costs are the 2,000 lowest costs. Each service member retained would then receive any NMIs allocated to him or her as well as a cash bonus whose amount depends upon the pricing rule being used, as described in the next section.

3. Price Determination: Discriminatory vs. Uniform

The basic discriminatory-price and uniform-price auction rules were described in the early chapter on auction mechanisms. Although a bit more complex, the basics of these two pricing rules translate readily to pricing under CRAM.

Under discriminatory-price CRAM variations, each retained service member receives the exact cash bonus he/she requests and, under the bid-method, pays out of this bonus the exact amount he/she bid for each NMI allocated. Thus, under the discriminatory-price CRAM, each retained service member receives a cash bonus given by:

Cash Bonus = "Post-NMI" Cash Incentive Bid

Recall that, under a traditional uniform-price auction, all winning bidders pay or receive an amount equal to the first excluded bid. As implemented under CRAM, the uniform-price rule dictates that each winning bidder receives a retention package (cash plus NMIs) whose total cost is equal to the first-excluded retention cost (the lowest total retention cost among those service members not retained).

Thus, under the uniform-price CRAM, each retained service member receives a cash bonus given by:

Cash Bonus = First Excluded Total Retention Cost – Total Cost of Allocated NMIs

Under all CRAM variations, the total value to the service member includes the service member's cash bonus plus the value of any allocated NMIs. If service members have selected or bid for NMIs wisely, the value to the service member should exceed the cost for all allocated NMIs, and thus the total value received by an individual

will always be either equal to or greater than the actual cost to retain the service member.[44]

L. EXAMPLE OF CRAM IN ACTION: UNIFORM-PRICE BID-METHOD

As further illustration of how the Combinatorial Retention Auction Mechanism operates, consider an example of the uniform-price bid-method CRAM with three Navy sailors being considered for retention and two NMIs offered, each costing the Navy $20,000 to provide. For the purpose of this example, suppose that two of these three sailors are to be retained and that NMI values are additive. Figure 14 illustrates such a scenario and how the uniform-price bid-method CRAM would be applied. The columns two through four in the figure show the sailors' cash only costs to retain (i.e., true reservation value), and the values they receive from each of two NMIs, respectively.

[44] Peter J. Coughlan, William R. Gates and Brooke M. Zimmerman, "The Combinatorial Retention Auction Mechanism (CRAM): Integrating Monetary and Non-Monetary Re-Enlistment Incentives," (Techincal report, Naval Postgraduate School, 2009), 78.

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 14. Example: CRAM (From Coughlan and Gates, 2007)

If a purely monetary uniform-price retention auction were used, the sailors would optimally bid their true reservation values (column two). Thus, sailors 1 and 2 would be retained at a bonus equal to the bid submitted by sailor 3 ($100,000), and the total cost to retain two out of the three sailors would be $200,000.

Under the uniform-price bid-method CRAM, on the other hand, the sailors would also do best by bidding their true value for each of the NMIs. Thus, sailor 1 would be allocated NMI 1, sailor 2 would be allocated NMI 2, and sailor 3 would be allocated NMIs 1 and 2, resulting in the NMI costs and values shown in columns five and six, respectively.

The military would then reduce the cash incentive bids by the value (or bids) for the NMIs allocated, resulting in the revised cash retention bonus depicted in column seven.

The military cost to retain each sailor, their revised cash bid plus the cost of the selected NMIs, is provided in column eight. Sailor 2 would thus be separated under CRAM and would set the total retention cost for the retained sailors, $80,000 per sailor. Hence, CRAM reduces the total cost to retain two sailors to $160,000, saving $40,000 with just two sailors.

The final two columns in the figure show the cash bonus paid to each retained sailor (the military cost for the first excluded sailor minus the cost of NMIs awarded), and the total value received by each sailor (their cash bonus plus the value of the NMIs awarded). The sailors receive a $30,000 greater value than with a monetary auction alone, totaling $230,000, because of the NMIs provided.

M. CHAPTER SUMMARY

The CRAM is a tool that incorporates a combination of monetary and NMIs and uses the truth revealing second-price sealed-bid auction to determine the most cost effective service members to retain. The mechanism can increase value for the individual while ensuring cost savings for the military services. This research further investigates the effects of combinatorial NMI values and attempts to determine if individuals make rational decisions in such complex scenarios.

IV. EXPERIMENTAL ECONOMICS

A. CHAPTER OVERVIEW

Economics studies the choices made under conditions of scarcity.[45] Like many sciences, economics is observational, meaning that theories can be tested and evaluated by analyzing data. Data can be obtained numerous ways, conducting an experiment is one form of data collection and this practice is known as experimental economics.

The following chapter provides an introduction into experimental economics, discusses types of economic experiments, reviews advantages and limitations, and then looks at procedural and design considerations. Much of the chapter is referenced from Davis and Holt, Experimental Economics. Ultimately the chapter gives reason and support for the experiment conducted in this research.

B. INTRODUCTION TO EXPERIMENTAL ECONOMICS

Econometricians have traditionally obtained data from existing "natural" markets to test economic theories and develop models.[46] Models attempt to untangle the effects of interrelated variables while maintaining a level of statistical significance. Depending on the hypothesis being tested and the type of data obtained, extraneous factors may bias the results and lower the predictive power of the model. This becomes even more critical and challenging when

[45] Marc Lieberman and Robert E. Hall, *Introduction to Economics, Second Edition*, (South-Western, 2004), 1.

[46] Douglas D. Davis and Charles A Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 3.

predictions depend on behavioral assumptions, which are difficult to observe in natural markets.

Other sciences, such as biology, have attempted to remove and limit extraneous factors when testing theories by systematically collecting data in controlled laboratory conditions. Davis and Holt continue with the concept and say, "Although the notion is somewhat novel in economics, there is no inherent reason why economic data cannot also be obtained from laboratory experiments."[47] The idea of using experiments to test economic theories or mechanisms is relatively new; however, it has caught on and has served an important role in filling the gap between theory and observations.[48]

While economic experiments are not the cure-all for future economic research, they hold many advantages as models become more complex.

C. TYPES OF ECONOMIC EXPERIMENTS

1. Market Experiments

Spurred by the market failures during the 1930s Great Depression, Edward Chamberlin studied the theory of monopolistic competition.[49] To test his hypotheses of how markets operated he set up simple economic experiments using graduate students as subjects. Chamberlin used cards marked with various values and costs and directed students to trade, negotiate, buy, and sell with the goal of earning

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[47] Douglas D. Davis and Charles A Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 4.

[48] Ibid., 4.

[49] Ibid., 6.

hypothetical money. The students moved around a room buying and selling amongst each other. He was able to identify and observe supply and demand curves and create price and quantity predictions.

Chamberlin's research was published in 1948 and was widely ignored, even by himself, due to the novelty of the method.[50] Fifteen years later, a researcher named Vernon Smith, a prior student of Chamberlin, conducted follow-on research concerning market experiments. His research involved experiments in which all the data (bids, offers, and transaction prices) were public knowledge. Again, the research did not stir much interest but it led the way for studies involving competitive price theory.

In sum, market experiments marked the beginning of experimental economics and they involve studying buyers and sellers who are jockeying for an equilibrium price (where supply meets demand).

2. Game Experiments

Game experiments were derived from game theory. Game theory analyzes the strategic behavior of individuals when an individual's choice depends on the choices of others. The most well known applied example of game theory is the "prisoner's dilemma." The following is an example of the situation:

> Suppose that two alleged partners in crime, prisoner A and prisoner B, are placed in private rooms and are given the same opportunity to confess. If only one of them defects and gives

[50] Douglas D. Davis and Charles A Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 6.

> evidence for the prosecutor, the other receives a ten-year sentence, and the prisoner who confesses goes free. If both remain silent, both prisoners are sentenced to only one-year in jail for a lesser charge. If both confess, however, they each serve five-year terms. Each prisoner must decide to either betray or remain silent.[51]

Figure 15 presents the "prisoner's dilemma" in matrix form. The situation creates an obvious problem, each prisoner would be better off if neither confessed but each is aware of the other's incentive to confess. This scenario is easily applied to duopoly pricing strategies, in which Firm A or Firm B has an incentive to drastically decrease the price of a service or good and take market share and profit from the other. For example, Firm A lowers the price of a good and takes business away from Firm B. In response Firm B lowers prices to regain market share and profit. In the end both firms are making less profit and worse off.

		Prisoner B: Confess	Prisoner B: Don't Confess
Prisoner A	Confess	(-5,-5)	(0,-10)
	Don't Confess	(-10,0)	(-1,-1)

Figure 15. The Prisoner's Dilemma

[51] Modified from Douglas D. Davis and Charles A Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 7.

The main point in a game experiment is that an individual's decision dependents on another person's possible actions. Through game experiments, researchers can investigate the strategic behavior of individuals when their best choice of action depends on the actions of others.

3. Individual-Choice Experiments

Individual-choice experiments, unlike game experiments, do not require strategic behavior, only that an individual seeks to optimize their position. These forms of experiments may deal with decision theory, which attempts to quantify the process of choosing between competing alternatives.[52] An experiment may include the choice to select two uncertain prospects with differing probabilities, uncertainty, or risk. Individuals try to maximize their gain; however, not all individuals act the same. The reason why individuals might act differently is because of differing risk tolerances and information.

An example of how different risk tolerances might influence two people can be seen in the following scenario. One situation has a guaranteed payoff of $10 for simply participating. The other situation involves flipping a coin for a potential payoff of $25 if heads, and $0 if tails. The first scenario has a guaranteed payment of $10 and the second scenario has an expected value of $12.50 ($25 * 0.5 + $0 * 0.5 = $12.50). A risk-averse person might choose the first scenario for $10 because there is no

[52] Principia Cybernetica Web, Decision Theory, http://pespmc1.vub.ac.be/ASC/DECISI_THEOR.html (accessed 20 February 2010).

uncertainty; a risk-neutral person would select the second scenario because of expected value of $12.50.[53]

Individual-choice experiments are important to the military because they can shed light on peoples' behavior when dealing with decisions of uncertainty. Scenarios of uncertainty include decisions where individuals are trying to decide to stay in the military or leaving for the private sector.

D. ADVANTAGES AND LIMITATIONS

The main advantage of experimentation is replicability and control. Replication provides the opportunity to conduct numerous sessions while reducing variability, allowing for a bigger data sample and increased significance and confidence levels. Additionally, replication is crucial in most areas of study, allowing others to independently reproduce the results and evaluate the analysis. Controls are used in experiments to focus the purpose of the research. Natural markets are influenced by countless seen and unseen forces that influence decisions, by simplifying and controlling many factors and using assumptions researchers can focus the experiment.[54]

There are limitations to running experiments. The most common limitation is that experiments only test a specific hypothesis and do not develop alternative

[53] 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), 26.

[54] Douglas D. Davis and Charles A. Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 14-15.

hypotheses. The results of an experiment can only prove or disprove a specific hypothesis and if a theory is proven wrong a new hypothesis must be developed. Another limitation is the concern of over simplification. Just as controlling for extraneous factors are useful, it can also present challenges. Experiments are supposed to help explain the real world; however, experiments are based on a simplified version of the real world.

The subject pool which participates in an experiment may present another limitation to experiments. Since most subjects are volunteers there might be selection bias. Additionally, many of the research subjects tend to be graduate students. Again, experiments are supposed to examine real-world markets and scenarios; however, only a small percentage of the population has graduate degrees. By understanding the limitations, efforts can be taken to identify and address potential issues.[55]

In sum, experiments provide many advantages; however, they should "complement rather than substitute for other empirical techniques."[56]

E. PROCEDURAL AND DESIGN CONSIDERATIONS

Design and procedural considerations can be categorized into five groups; procedural regularity, motivation, unbiasedness, calibration, and design parallelism.[57] Each group will be briefly reviewed, explaining its significances.

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[55] Douglas D. Davis and Charles A. Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 16-18.

[56] Ibid., 18.

[57] Ibid., 21.

Before moving forward, it is customary to introduce specific terminology. There is no one official standard for experimental language; however, the following terminology will be used for this research.

1. Session: a sequence of periods, games, or other decision tasks involving the same group of subjects on the same day.
2. Cohort: a group of subjects that participate in a session.
3. Treatment: a unique environment or configuration of treatment variables, i.e., of information, experience, incentives, and rules.
4. Cell: a set of sessions with the same experimental treatment conditions.
5. Experiment Design: a specification of sessions in one or more cells to evaluate the propositions of interest.
6. Experiment: the collection of sessions in one or more related cells.
7. Trading period, game, or trial: the individual unit used to describe separate decisions within a session for market experiments, game experiments, or individual-choice experiments respectively.

1. Procedural Regularity

Detailed and explicit instructions are critical to executing a successful experiment. The instructions should be written in a way that allows anyone to read them to the subjects and holds everything else constant, the results should be similar. Thorough documentation of the experimental process assists with the professional credibility. Ultimately, detailed instructions should allow others to validate, replicate, and/or modify the experiment.

2. Motivation

To motivate participants to behave like they would in real life, incentives must be used to reward desired actions. In general, rewards are monetary because of the relatively homogeneous value individuals place on money and the unlikelihood of experiencing the law of diminishing returns given the size of the monetary payments. Food or materialistic goods are not good tools to motivate participants because each individual may value the good differently and, therefore, have differential incentives, whereas money is generally given equal weight by most individuals. The law of diminishing returns is experienced when an individual's demand for a good becomes less and less as the individual receives an increasing amount of that good. For example, if mini chocolate bars were used as an award, the first few might have tasted good; yet, after a while, the individual would no longer desire chocolate bars and lose the incentive effect when rewarded with chocolate. Money, unlike chocolate, does not easily lose its appeal and, therefore, it is a good tool to incentivize people.

While money serves as a good tool to motivate subjects to actively participate, it does not increase the subjects' abilities. "No amount of money can motivate subjects to perform a calculation beyond their intellectual capacities, any more than generous bonuses would transform most of us into professional athletes."[58] With this understanding, money still is considered the best incentive.

[58] Douglas D. Davis and Charles A. Holt, *Experimental Economics* (Princeton, NJ: Princeton University Press, 1993), 24.

3. Unbiasedness

The subjects used are also important to the success of an experiment. Depending on the purpose and subject of the experiment, it might be important to target certain volunteers; military, graduate students, or the general public. Since subjects volunteer for the experiment, self-selection bias might become an issue. Self-selection bias is observed when those who volunteer to participate in an experiment are significantly different from those who do not participate. By understanding the subject pool, it can be argued that self-selection bias is not present.

When explaining the experiment to the subjects, it is vital to avoid suggestive behavior or language, particularly in recruiting subjects (the research questions should not be described). Other than the instructions, which were provided to all the subjects, no other information should be selectively given to individuals.

Another important aspect of experimental economics is maintaining the trust and respect of the participants. If a participant feels lied to or perceives any deception, the quality of the individual’s responses is questionable and should likely be discarded.

4. Calibration

Obtaining quality data is the primary goal for conducting experiments; to ensure the data is valid, it must be calibrated. Calibration provides an outline and a clear understanding of the baseline and the variations to be measured. The base line is used to evaluate the subjects before any treatment or procedure is introduced.

By understanding the baseline and then observing the treatment data, the effects can be measured and studied. Additionally, it is important to focus the treatment and not change too many conditions in one session. The data will be increasingly difficult to analyze if many treatments are introduced.

Order of scenarios during experiment sessions is also a major concern because of potential participant learning effects. For example, subjects may be asked to provide requested bonus amounts during the first few trials and these answers become the baseline. Then a treatment tool is introduced and the subjects are asked to provide more bonus requests. The difference between the first cell and the second cell can be attributed either to the treatment or the participants' learning effects. Different methods may be used to control for the learning effect. Experimenters may change the order of the treatments, mix the treatment and control trials together, or even use only one cohort per treatment. Each method has its advantages and disadvantages; by understanding the potential for this unwanted effect, steps can be taken to control for it.

5. Design Parallelism

The experiment should attempt to resemble reality as closely as possible vice the theories devised by economists.[59] At the same time, the experiment should be simplified and focused to evaluate the specific topic. There is a balance that should be maintained; too much

[59] Douglas D. Davis and Charles A. Holt, *Experimental Economics*, (Princeton, NJ: Princeton University Press, 1993), 32.

complexity results in data that is difficult to analyze and subjects who may have trouble understanding the main experimental concept.

F. WHY THE MILITARY SHOULD CONDUCT ECONOMIC EXPERIMENTS

Before the military commissions a new weapon system or vehicle, it goes through a myriad of tests and experiments. There is no reason why potential policy changes and manpower issues should not go through the same rigors.

The main benefits of running experiments are the cost savings and the ability to capture human behavior. Cost savings are recognized by evaluating issues in a controlled setting before fully implementing the new policy or process. More importantly, experiments capture the human element. Theoretical models and statistical analysis can only go so far, however. Experiments provide the link between theoretical models and human behavior

G. CHAPTER SUMMARY

Experimental economics is a relatively new area of study, which has shed more light on market, game, and individual-choice theories. Replicability of experiments is a major advantage, which allows for the others to validate and conduct follow on research on various topics.

Successful experiments require detailed design and specific procedural considerations. By following basic guidelines an experiment can provide excellent data and provide insight in how individuals make economical decisions.

V. EXPERIMENT

A. CHAPTER OVERVIEW

The following chapter provides the experiment objectives, design, and hypotheses. The experiment investigated both the discriminatory-price and uniform-price variations of the menu-method CRAM. In order to obtain a large enough sample size for statistical significance, it was necessary to limit the focus of the experiment to these two variations of CRAM. The experiments conducted investigated individual behavior and mechanism performance in the presence of NMIs with both independent and combinatorial values.

B. EXPERIMENTAL OVERVIEW

1. Recruitment

Subjects were recruited through e-mail. A mass e-mail was distributed to the Graduate School of Business and Public Policy at the Naval Postgraduate School (NPS) requesting volunteers to participate in a decision-making experiment. The letter used to solicit volunteers is provided in Appendix B.

2. Purpose and Design

The goal of the experiment was to evaluate individual choice and bidding behavior as well as overall CRAM mechanism performance, particularly in the presence of NMIs with interdependent combinatorial values. The experiment isolated compensation, salary and NMIs, as the primary motivator for choice of employment between two generic

firms, Firm A and Firm B. Firm B's standing salary offer represented an individual's opportunity cost and, therefore, it became the individual's reservation value. This is what the person could earn if they left Firm A. In comparison to the military, Firm B's offer represents what someone could make in the civilian sector. The experiment was designed not to be military specific, or have any military reference, to remove bias. The decisions presented were identical to what a service member would experience in real life. The experiment was broken into three treatments: first, a purely monetary retention auction; then, menu-method CRAM with NMIs having independent additive values; and then menu-method CRAM with NMIs having interdependent combinatorial values.

3. Scenario

In the experiment, subjects were put in the role of one of a hundred employees at Firm A making an employment decision. In the scenario, Firm A is downsizing by 50 percent. Another generic company, Firm B, is offering to employ all former employees from Firm A. Subjects have no preference for either firm and are only interested in maximizing their personal compensation. Firm B offers each a different salary amount; each subject in turn then must submit a salary request to Firm A. Once the bid is submitted, there is no way to change the bid for that trial. No matter what happens, a subject will either continue working for Firm A or get laid off and work for Firm B. The experiment introduces NMIs and repeats this process for each trial. The instructions used for the experiments are in Appendix C.

The experiment itself comprises 30 trials and is broken into three treatments, ten (10) purely monetary trials, ten (10) independent NMI trials, and ten (10) combinatorial NMI trials (with potentially sub-additive or super-additive values). The trials are set up in a pyramid style, as shown in Table 1. The reason for the pyramid style is to gradually introduce complexity into the process and identify learning effects by later eliminating the complexity. Also, experiments are conducted using both the discriminatory and uniform pricing rules to compare the two alternatives. The experimental language used is in Appendix D.

Table 1. Experiment Structure

Experiment Structure	
Rounds 1 – 5:	Monetary Only
Rounds 6 – 10:	Independent NMIs
Rounds 11 – 20:	Combinatorial NMIs
Rounds 21 – 25:	Independent NMIs
Rounds 26 – 30:	Monetary Only

C. EXPERIMENTS

Before each of the three different treatments, practice rounds are conducted to ensure subjects understand the layout and the goal of the scenario. The practice rounds show the subjects every possible outcome.

1. Monetary Cash Bid Only

In the initial cash bid only experiment, subjects are one of a hundred employees at Firm A. Just as described

above, Firm B offers a salary amount, and the subject must submit a bid to Firm A. Based on the salary requests submitted, those employees who submitted the 50 lowest bids are kept with Firm A. The 50 highest requests are laid off and employed at Firm B.

2. Cash Bid Plus Independent NMIs

Very similar to the purely monetary cash bid, now Firm A offers two generic NMIs. Firm B still only provides a monetary salary if laid off from Firm A, the subject's reservation wage. The two NMIs are listed and are given a value and a cost. The value provided is the amount the individual values the NMI. The cost is the amount it costs for Firm A to provide that NMI. If the subject values the NMI at more than cost, it should be selected. Subjects are able to select neither, one or both NMIs should they so choose; the values and costs are purely additive.

3. Cash Bid Plus Combinatorial NMIs

This scenario is identical to the previous scenario, except now the NMI values are interdependent, in that NMI 1 by itself is valued by the amount presented and NMI 2 by itself is valued by the amount presented. However, when NMI 1 and NMI 2 are selected together, their values may be sub-additive, additive, or super-additive. Subjects are told their value for the NMIs in combination as well as the "stand alone" value of each NMI. Unlike NMI values, the NMI costs remain additive in this treatment.

D. OPTIMAL COMBINATIONS OF NMIS

For every round that included NMIs, rounds 6-25 in this case, there are four options each subject can choose:

1. No NMIs
2. NMI 1 only
3. NMI 2 only
4. NMI 1 and 2 together

In each case, the subject should select the NMI option that creates the most surplus value (total value minus total cost). When purely additive, if NMI 1 and 2 are each valued less than the associated cost to provide, then the optimal choice is to not select any NMIs. On the other hand, if NMI 1 and NMI 2 are each valued at greater than the associated cost, it is optimal for the individual to select both. The same concept works for the NMIs individually as well.

The decision process is more complicated for NMIs with combinatorial values. One must look at each combination individually and determine the greatest surplus achieved. There may be instances when both NMIs have values that exceed costs, but it is optimal to only select one of the two NMIs (because they are substitutes); similarly there may be times when neither NMI has a value that exceeds cost independently, but it is optimal to select both in combination (because they are complements).

1. Combinatorial NMI Values Under Bid-Method CRAM

Since the CRAM may allocate individuals various combinations of NMIs, it is important to evaluate if the

mechanism (and/or each individual participating in the mechanism) appropriately incorporates and adjusts for the presence of super- and sub-additive NMI values. Inefficient separation and retention errors can occur as a result of adding individual NMI values vice using the combinatorial values.

Table 2. Illustration of Problem Scenarios and Non-Problem Scenarios When Assuming Additive Valuations (From Ellis, 2009)

Scenario	Min Cash to Retain	Value for NMI A	Value for NMI B	Value for both NMIs	Cost per NMI	Assumed Cost to Retain	Actual Cost to Retain	Cutoff Cost to Retain	Cash Incentive	Offered Retention?	Willing to Retain?	Problem?
1	40	10	10	30	8	36	26	40	24	Yes	Yes	No
2	40	10	10	30	8	36	26	30	14	No	Yes	Yes - Retainable @lower cost
3	40	10	10	30	8	36	26	20	4	No	No	No
4	40	10	10	17	8	36	39	44	28	Yes	Yes	No
5	40	10	10	17	8	36	39	38	22	Yes	No	No - Retainable with 1 NMI
6	40	10	10	17	8	36	39	32	16	No	No	No
7	40	10	10	17	6	32	35	38	26	Yes	Yes	No
8	40	10	10	17	6	32	35	34	22	Yes	No	Yes - Can't retain at cutoff cost
9	40	10	10	17	6	32	35	30	18	No	No	No

Table 2 presents example scenarios of super- and sub-additive NMI values and how each could potentially create a problem for CRAM implementation via the bid-method. The next section will explain how the menu-method CRAM can potentially correct these problems.

The CRAM process illustrated in Table 2 is that of the uniform-price bid-method CRAM variation. It is also assumed in the table that the bidder in question submits

his true reservation value as the cash bid and his true NMI value in bidding for each NMI. Note that this would, in fact, be the optimal bidding strategy if NMI values were additive.

Columns two through six represent the minimum cash to retain (which is equal to the reservation value as well as the cash bid), the values for NMI A and B, respectively (which, again, is also the assumed bids for NMI A and NMI B), the values of NMI A and B combined and the cost to provide each NMI. Column seven represents the assumed cost to retain if the mechanism treated NMI values as additive; minimum cash to retain minus the value of NMI A and NMI B independently plus the cost of NMI A and NMI B. Column eight represents the actual cost to retain using the true combinatorial NMI values; minimum cash to retain minus the value of both NMI A and NMI B plus the cost of NMI A and NMI B. Column nine and ten represent the hypothetical cutoff retention cost for the scenario and the cash incentive received; the cutoff cost to retain minus the cost of the received NMIs, respectively. The last three columns note if the individual was offered retention and if they were willing to retain, if the two columns do not match then there was a problem.

Note that, in all nine scenarios, the bidder in question submits a cash bid of 40 and a bid of 10 for each NMI. Because the cost of each NMI is less than the bid of 10 in all scenarios, the bidder will be allocated both NMIs in all cases explored. Moreover, if the mechanism treats

NMI values as strictly additive, in each scenario the total value of NMIs received will be assumed (incorrectly) to be equal to 20.

The first three scenarios in Table 2 illustrate super-additive NMIs; scenarios 1 and 3 are not problematic since those who wish to be retained are offered retention and those who do not want to be retained are not offered retention. Scenario 2, however, demonstrates problems where assuming additive NMI values in the bid-method CRAM results in an individual not being offered retention. The additive cost to retain was 36 and the actual cost to retain was 26, which is under the cutoff cost to retain of 30. The individual wanted to and could have been retained if the values of NMIs were properly calculated. Additionally, the military service would have been better off and the bidder would have gained value if he or she was retained. This is a case of inefficient separation, because an individual was separated when they should have been retained.

The next six scenarios in Table 2 are sub-additive and demonstrate potential problems when use additive NMIs vice the combinatorial values. Scenarios 4, 6, 7, and 9 produce no problems; those who want to be retained are offered retention and those who do not, are not offered retention. Scenario 5 and 8 both represent potential problems due to adding individual NMI values vice using the true combinatorial values. Scenario 5 results in the individual being offered retention; however, the individual is not better off and should not want to be retained at the amount offered. In this case, it would be beneficial for the

individual to only select one NMI, resulting in gained value. Scenario 8 is problematic because the bidder is offered retention using the additive NMI values; however, the bidder would not want to be retained using the combinatorial NMI values. These scenarios result in inefficient retention errors, because an individual was retained when they should not have been.[60]

2. Combinatorial NMI Values Under Menu-Method CRAM

The menu-method CRAM can correct the three problem scenarios mentioned in Table 2. Instead of individually bidding for each NMI and then subtracting the original "cash" only bid request. The menu-method allows a bidder to select all the NMIs which are of value (none, one, all, or any combination) and then the bidder submits a single bid request which includes the monetary accounting for the NMI values. In other words, assuming bidders receive all the requested NMIs what additional cash is requested? The total cost of the individual would be the requested cash plus the cost of the requested NMIs. The research hypothesizes that subjects will select combinations of NMIs which create the greatest delta between value and cost.

E. OPTIMAL BIDDING STRATEGIES

After selecting the desired combinations of NMIs, the subjects must submit a salary request. Subjects have no preference between working for Firm A or B, only that their compensation is maximized. Again, the objective is to

[60] Jason B. Ellis, "Variability of Valuation of Non-Monetary Incentives: Motivating and Implementing the Combinatorial Retention Auction Mechanism," (Master's thesis, Naval Postgraduate School, 2009), 45-47.

maximize personal compensation. The discriminatory and uniform auction mechanisms are similar but they have different bidding strategies.

1. Discriminatory-Price Auction

Recall that a discriminatory auction is the multiple-winner generalization of the first-price auction. In the experiment, those who submit the 50 lowest total cost bids are retained by Firm A and are paid the salary they each individually requested, assuming no NMIs are offered; those who submit the 50 highest total cost bids are laid off from Firm A and immediately work for Firm B at the amount previously offered.

The subject must look at Firm B's offer, which becomes the subject's reservation wage, and then enter a salary request to Firm A. As previously discussed in Chapter III, if an individual was to bid truthfully in a discriminatory auction, he or she would not maximize their expected surplus value. Therefore, the optimal bidding strategy is to look at Firm B's offer and bid higher in relation to the expected range of offers.

2. Uniform-Price Auction

Unlike a discriminatory auction, in a uniform auction it is now in the best interest of the individual to bid truthfully. The optimal bidding strategy is to look at Firm B's offer, one's reservation wage, and then choose a salary request equal to the reservation wage (assuming no NMIs are offered).

3. Incorporating NMI Value

Now that the optimal salary request without NMIs has been discussed, the subject must incorporate the value of the NMIs selected. The individual will always know the NMI value. Therefore, the individual should always take the cash only salary request and subtract the value of the selected NMIs. This adjusted cash value is the optimal bid for each subject.

F. DESIGN CONSIDERATIONS

In Chapter IV, design considerations were discussed. They were procedural regularity, motivation, unbiasedness, calibration, and design parallelism. The experiment layout and design for this thesis drew heavily from Naval Postgraduate School (NPS) research conducted by William J. Norton in 2007. He designed a hypothetical experiment based on very similar concepts and ensured it met the key design considerations. Since then, other researchers have conducted experiments on this subject using the same style. By keeping the format and language similar and only changing key aspects provides the ability to compare data from previous experiments.

For this research, procedural regularity was maintained by strictly following the detailed instructions for each session. Motivation was achieved by providing an actual cash award at the end of the experiment based on choices made throughout the session. Unbiasedness was addressed by creating a general experimental context and specifically choosing language in the instructions and actual experiment that would not influence the subjects toward biased responses. Calibration can be ensured by

evaluating the responses and determining if any responses were out of the ordinary. If responses appeared to be rational and logical, then the experiment is calibrated to examine the objectives. Lastly, design parallelism was achieved by making the situation as realistic as possible while also controlling many variables.

G. HYPOTHESES

Hypotheses suggest that individuals should select the optimal NMI combination whether NMI values are additive or combinatorial. If the proportion of optimal NMI selections under both value conditions were statistically the same, then it suggests that the ability of individuals to make rational utility-maximizing NMI selections is not reduced when dealing with combinatorial NMI values.

Hypotheses propose that discriminatory and uniform bids will be statistically different. Difference can be attributed to the optimal strategies of each method. The uniform auction should result in individuals bidding near their reservation value with little reason to deviate. A discriminatory auction should result in more variability among individuals' bids as a result of the different optimal strategy. Other hypotheses tests are used to evaluate the expected learning effects in the earlier trials compared to the later trials.

H. CHAPTER SUMMARY

The experiment design focuses on determining if individuals make rational choices when dealing with combinations of NMIs. Do individuals figure out the optimal bidding strategy when using a uniform or

discriminatory auction mechanism? If an individual does find the optimal bidding strategy, do they then appropriately adjust their bid based on the NMIs selected. The following chapter presents the results of the experiment.

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VI. EXPERIMENT RESULTS

A. INTRODUCTION

Chapter V explained how the uniform-price and discriminatory-price CRAM variations operate in the presence of combinatorial NMI values. In the experiment, subjects were offered a salary from Firm B and in response they had to select NMIs, if offered, and submit a salary request to Firm A. The subjects' only goal was to maximize their personal compensation. This chapter discusses the sample and the results of the salary requests.

B. SAMPLE

The experiment was conducted using 51 participants from NPS. There were a total of three sessions; 4 February 2010 (1300-1500), 5 February (1200-1400), and 5 February (1500-1700). The sessions were conducted in a NPS computer lab with 18 desktop computers, 17 were operational. Each of the three sessions had maximum participation, 17 subjects for 17 computers. Each subject participated in 30 trials, thereby giving 1530 potential observations. The first session, 4 February at 1300, used a uniform auction mechanism to evaluate NMI selection. The last two sessions, 5 February at 1200 and 1500, used discriminatory auction mechanisms.

Due to data input errors and other factors, two of the 51 participants gave unusable data resulting in 1470 total observations from 49 individuals. Four other participants appeared to irrationally select NMIs, either all of them or none of them. The participants might not have understood

the concept of NMIs or were not taking the effort to specifically select the optimal combinations of NMIs. Their NMI responses (or lack of responses) were not included in the NMI analysis; however, their bid request was included in the analysis.[61] The four participants appear to have understood the bidding aspect of the experiment just not the NMI part. As a result, there were 1350 observations for NMI analysis.

Of the 1470 observations for the bid analysis, two bids from the same participant were well over the reasonable amount and were removed from the sample.[62] The participant might have been trying to test the program and figure out how it worked. Therefore, there were 1468 observations for the bid analysis. Notes of the sessions are located in Appendix E.

The largest demographic group represented was male military officers. Males represented 84 percent of the sample and females represented 16 percent as shown in Figure 16. Figure 17 shows that the rank of O3 represented 56 percent of the sample, with the rank of O4 at 29 percent. The ranks of O1, O2, and O5 were not highly represented. The Navy had the largest representation at 61 percent, as illustrated in Figure 18. The rest of the

[61] Position 1 on 2/4 at 1300, Position 7 on 2/4 at 1300, Position 5 on 2/5 at 1200, and Position 5 on 2/5 at 1500 were not included in the NMI analysis.

[62] Position 5 on 2/5 at 1200, rounds 3 and 23 were not included in the bid analysis.

United States (U.S.) services were represented less, between 17 percent and 6 percent. One civilian participated in the experiment. Figure 19 shows a reasonable spread over years of military service within the sample. The main categories of less than or equal to five years, ten years, fifteen years, and twenty years was generally represented by around 20 to 30 percent of the sample.

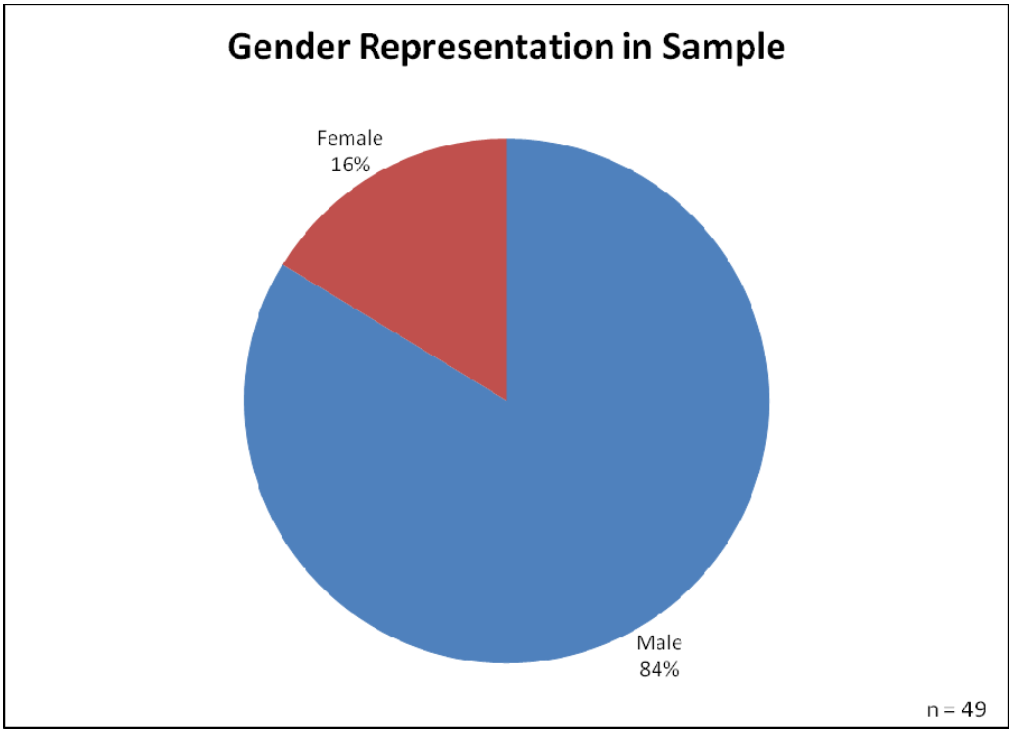

Figure 16. Gender Representation in Sample

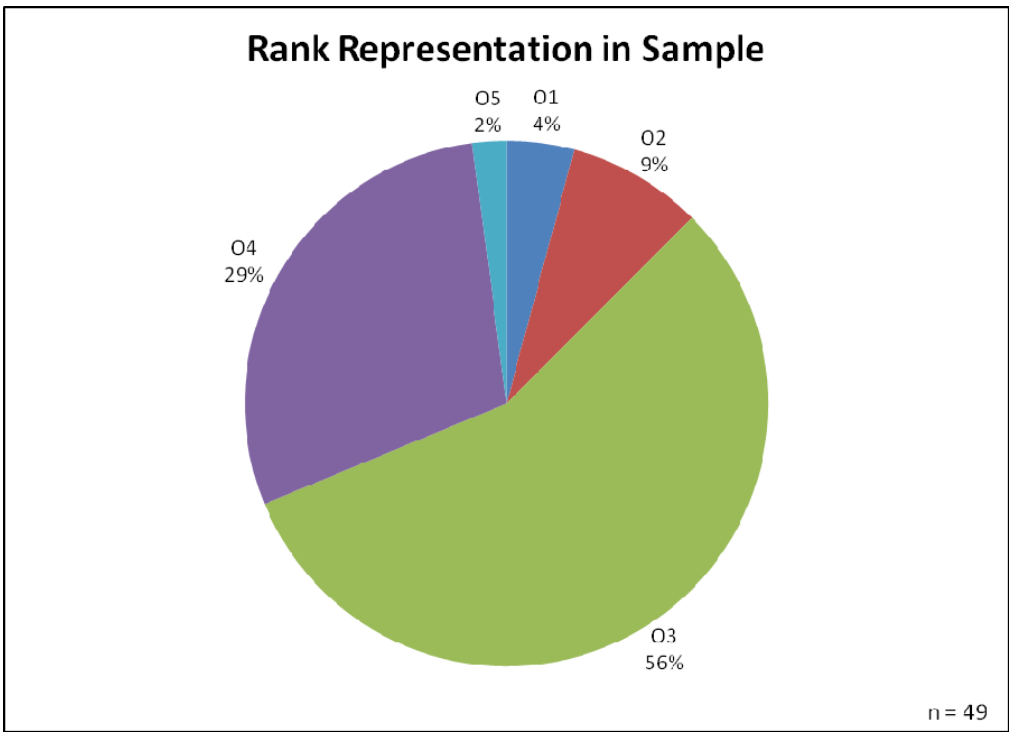

Figure 17. Rank Representation in Sample

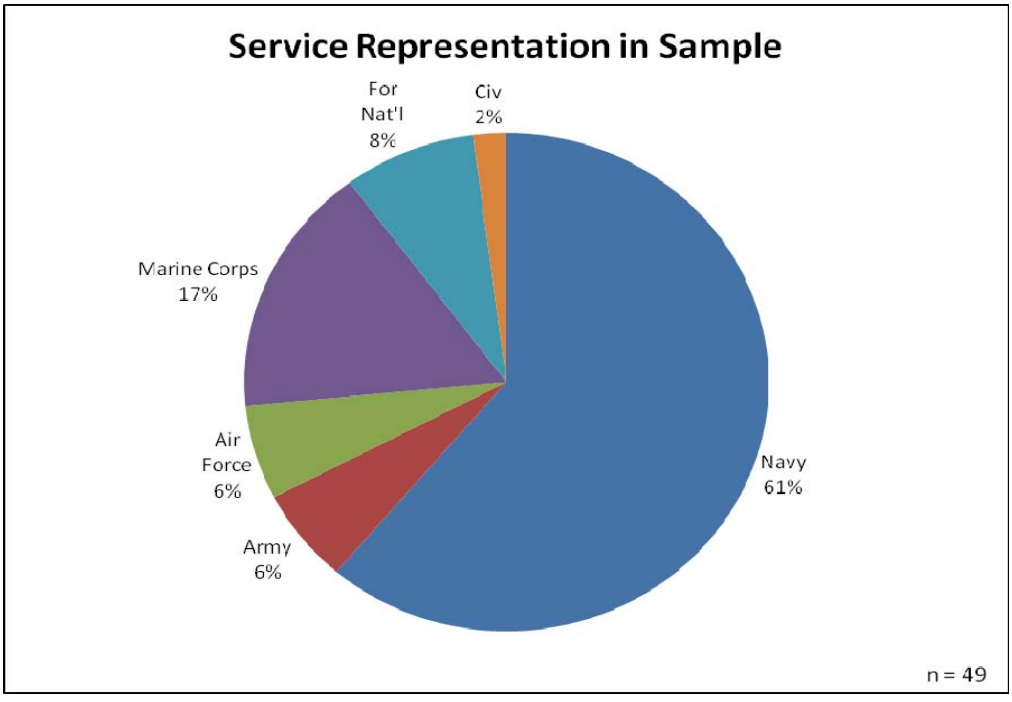

Figure 18. Service Representation in Sample

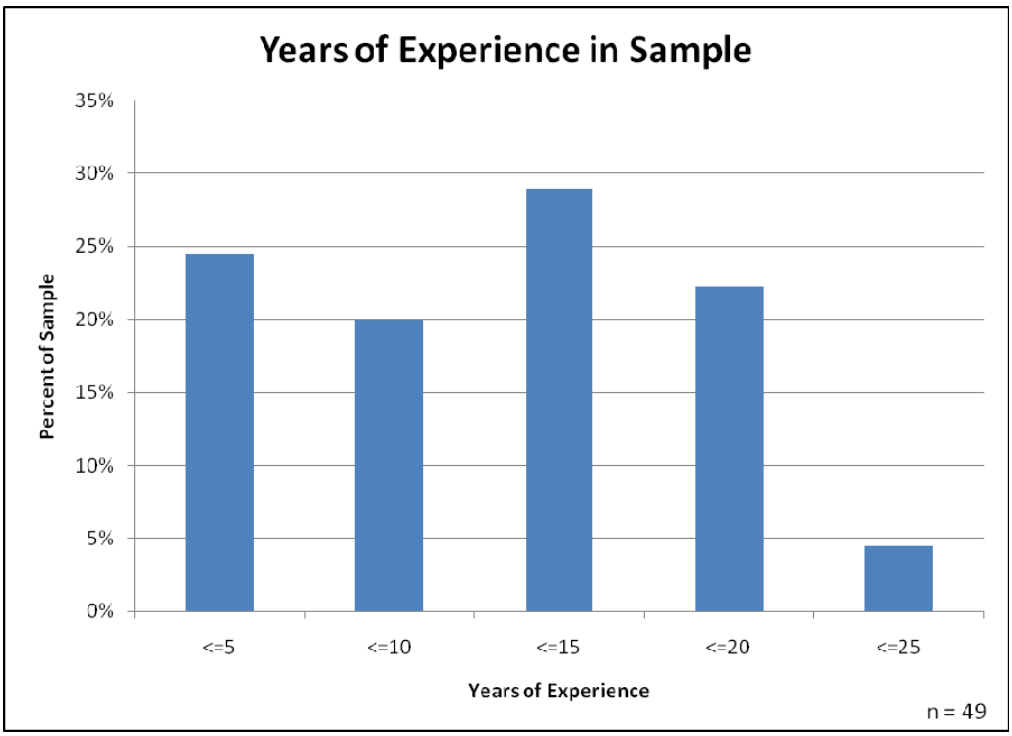

Figure 19. Years of Experience in Sample

C. NMI RESULTS

Out of the 1350 NMI observations, 900 included NMIs. In half (450) of the NMI observations, NMI values were purely additive, while the other half (450) included combinatorial values. The selected NMIs, by themselves, have little meaning. Only by calculating the optimal NMI combination for each trial and comparing it to the combination actually selected can meaningful data be evaluated.

1. Additive NMI Rounds

Did individuals select the combination of NMIs which created the greatest value (value - cost) when the values were additive? Yes, Figure 20 illustrates that 74 percent of the time individuals selected the optimal NMI

combination when the values were purely additive. There was a significant learning effect witnessed in the way individuals selected NMIs from the earlier rounds to the later rounds. Figure 21 shows that 67 percent of the subjects initially selected the optimal NMI combination; later in the experiment, using the exact same auction mechanism, 81 percent of the subjects selected the optimal NMI combinations.

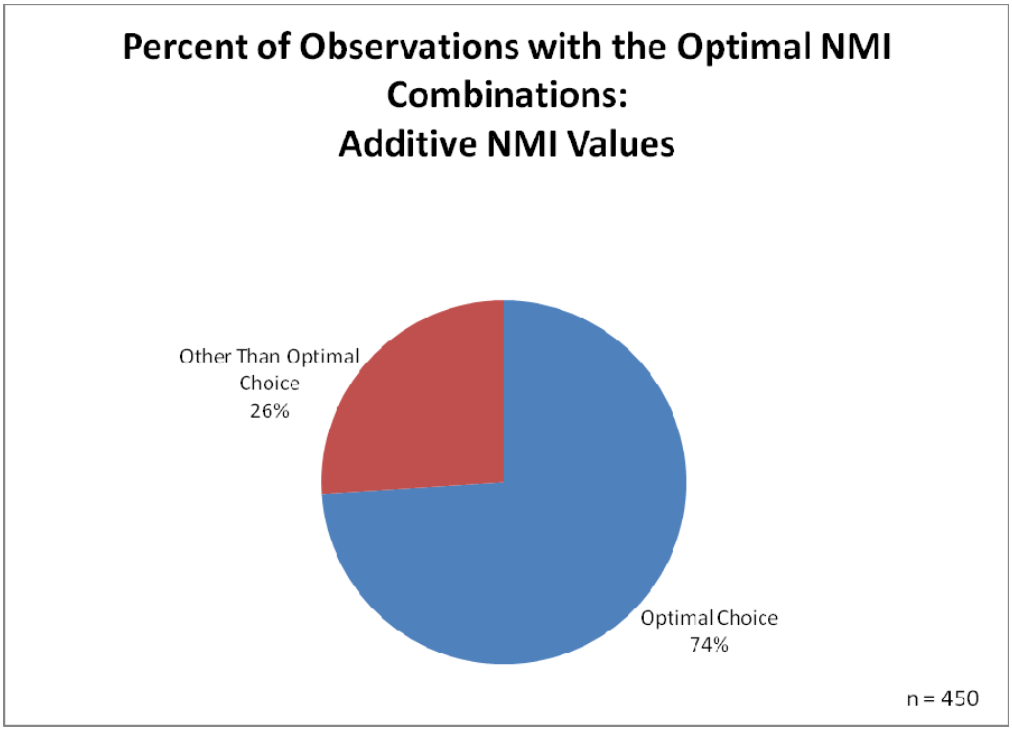

Figure 20. Percent of Individuals Who Selected the Optimal NMI Combinations – Additive Only

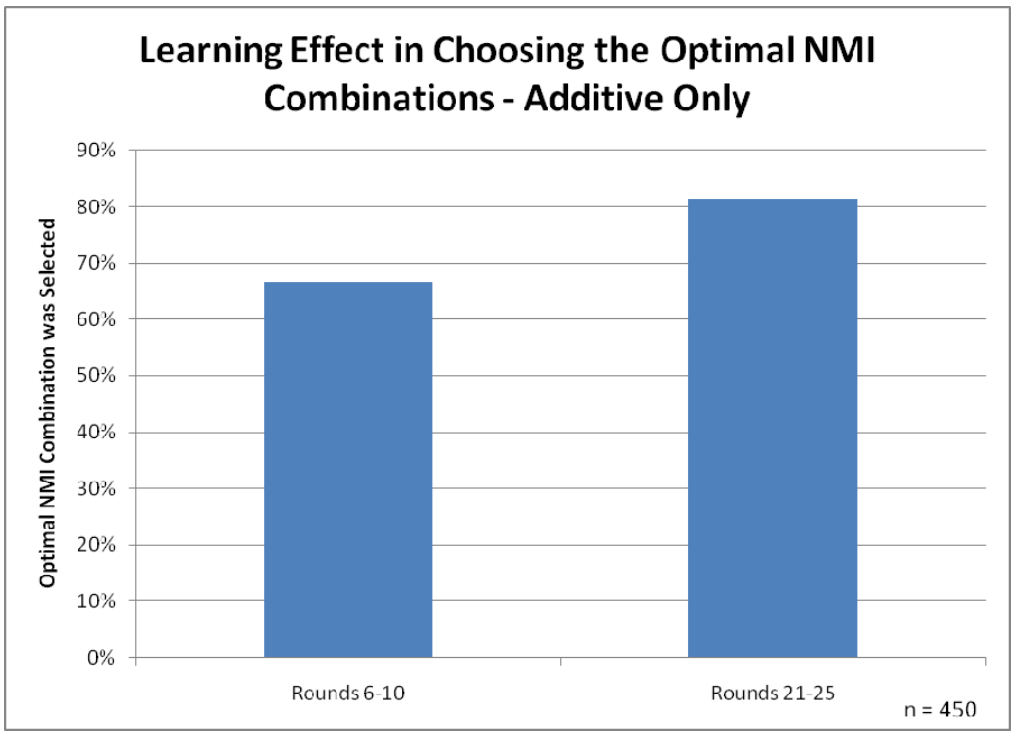

Figure 21. Learning Effect in Choosing the Optimal NMI Combinations – Additive Only

2. Combinatorial NMI Rounds

Did individuals select the combination of NMIs which created the greatest value (value – cost) when NMI values were combinatorial? In other words, did individuals look at the combinatorial value of the two NMIs to determine the greatest value? Yes, individuals did generally select the optimal combinations. Figure 22 illustrates that 70 percent of the observations selected the NMI combinations with the greatest value. Again, there was a learning effect seen throughout the progression of the experiment, which is shown in Figure 23. In the earlier combinatorial rounds, 67 percent of the observations selected the optimal NMIs combination; that percentage rose to 73 percent in the later rounds.

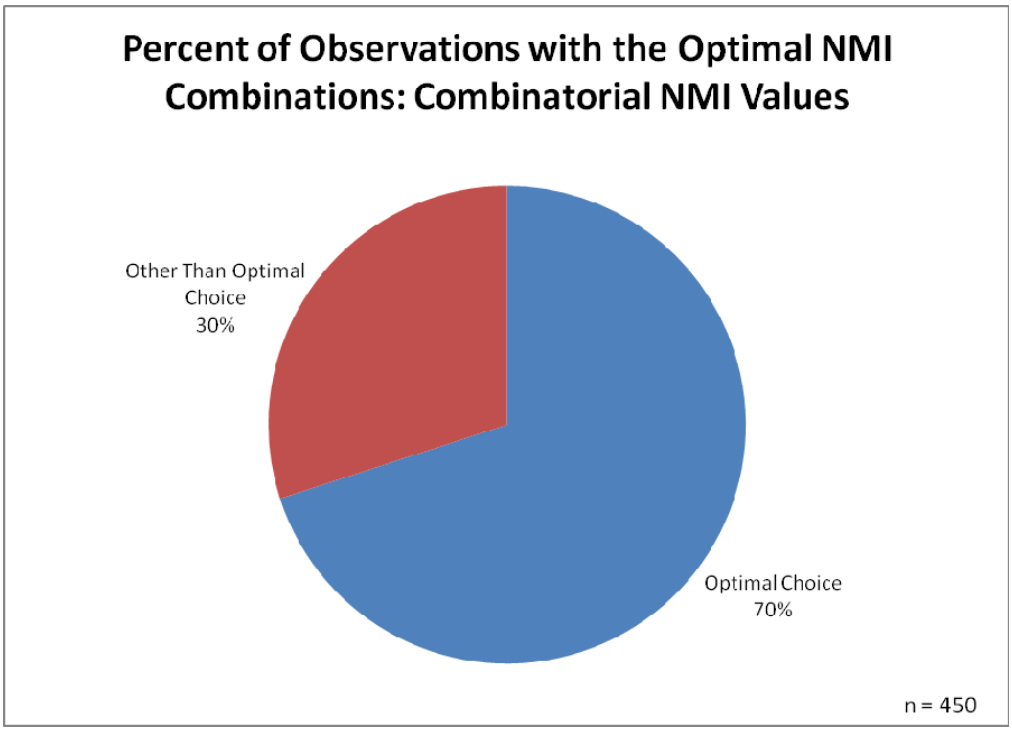

Figure 22. Percent of Observations with the Optimal NMI Combinations: Combinatorial NMI Values

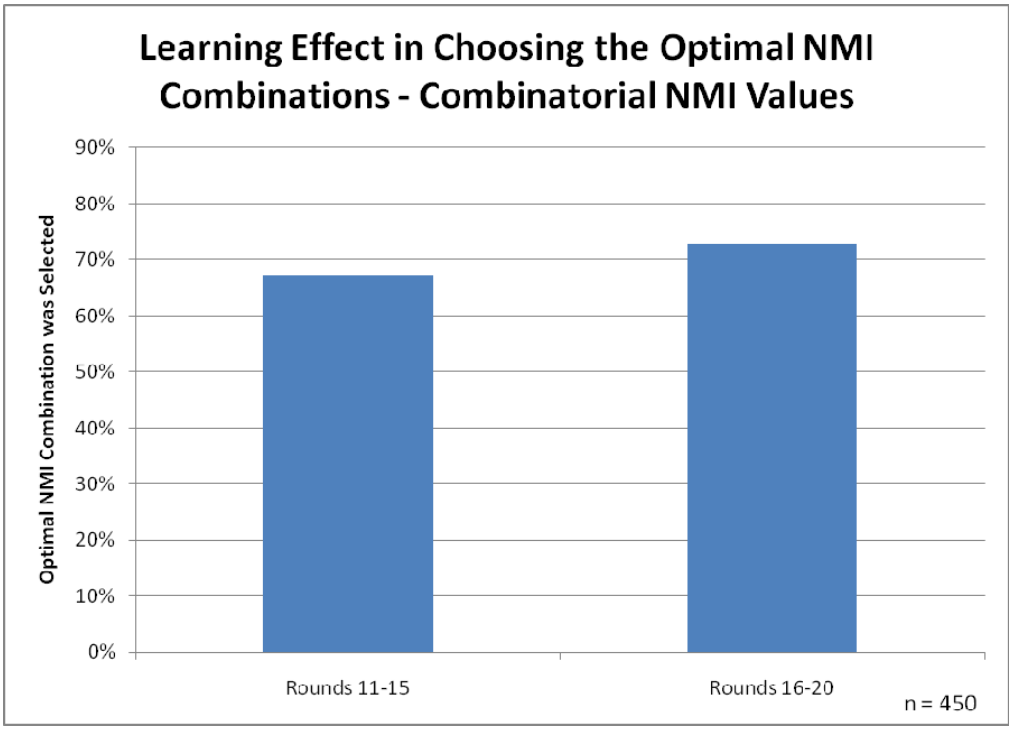

Figure 23. Learning Effect in Choosing the Optimal NMI Combinations – Combinatorial NMI Values

a. Did Individuals Ignore the Combinatorial Effects?

No, for the most part individuals did observe and the super-additive and sub-additive values for combinatorial NMIs. Figure 24 shows that only six percent of the observations selected NMIs which would have been optimal if NMI values were additive, but which were not optimal given the combinatorial values; 94 percent of the participants noticed combinatorial effects and selected the optimal NMI combination based on the combinatorial values, vice looking at the two NMIs individually and simply adding their individual values.

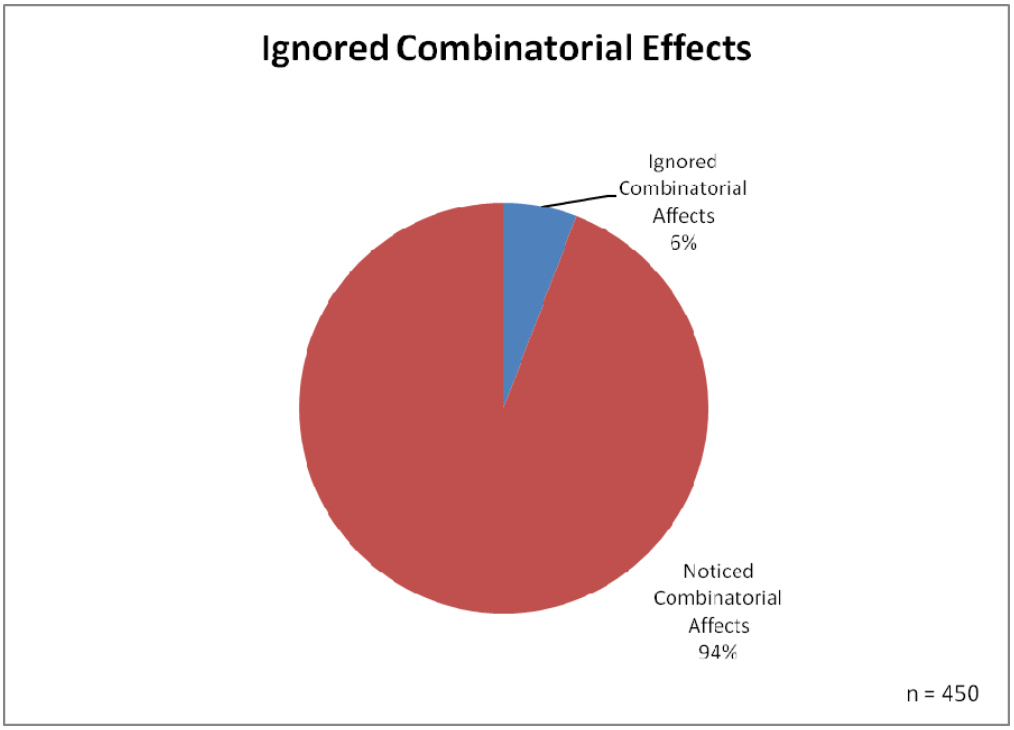

Figure 24. Ignored Combinatorial Effects

b. Did the Complexity of Combinatorial Values Result in Non-Optimal Choices?

Out of the 450 experimental rounds with combinatorial NMI values, 159 were considered "complex" choices. A complex choice is defined as one in which a NMI combination that is not optimal with additive NMI values becomes optimal with combinatorial NMI values, or vice a versa. In other words, individuals generally saw the created value (or de-value) in NMI combinations and purposely selected the optimum combination. Figure 25 shows that 66 percent of the complex choices were selected optimally, suggesting that individuals do react rationally to combinations of NMIs.

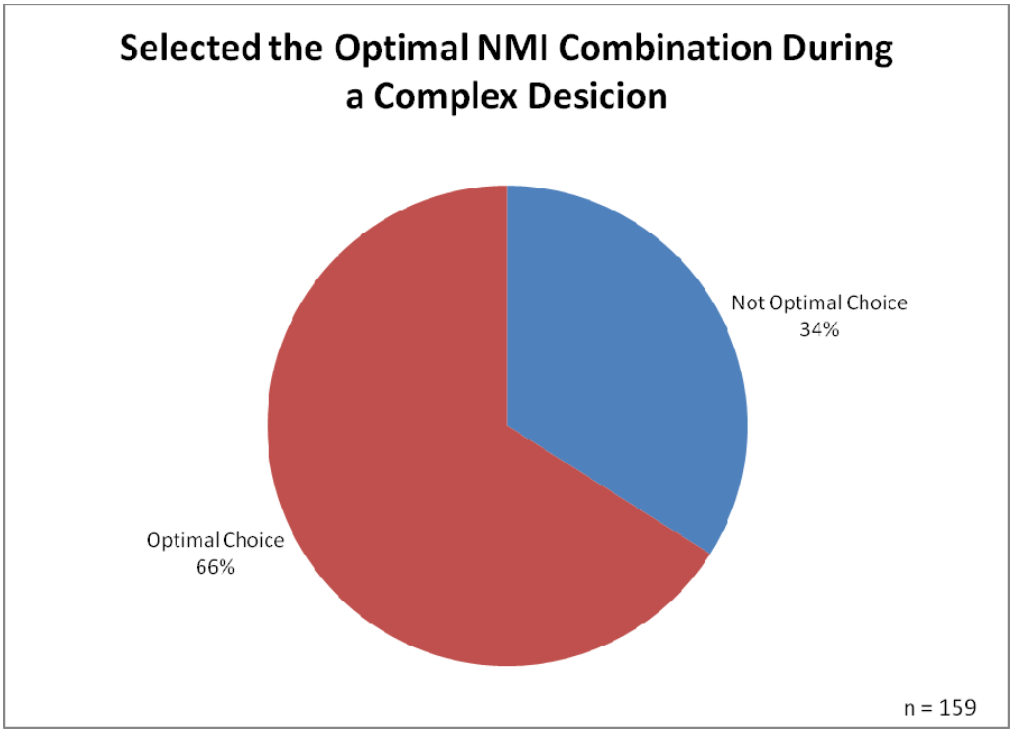

Figure 25. Selected the Optimal NMI Combination During a Complex Decision

3. Comparing the Additive and Combinatorial Rounds

It appears that the majority of the participants understood the concept of choosing the NMI combinations which created the greatest value. Recall, that at no time during the instructions were subjects told how they should select NMIs, only how their choices would affect (a) their likelihood of being retained by Firm A and (b) the value of their total compensation if retained. Individuals had to figure out that the greatest value was achieved by creating the greatest positive delta between value and cost. It appears that 74 percent of the observations during the additive rounds were able to select the greatest value; yet, in the combinatorial rounds the number dropped to 70 percent. The slight dip could be attributed to participants learning how to use NMIs to their advantage.

a. Combined Learning Effects

As previously mentioned, there appears to be a significant learning effect noticed in how individuals selected NMIs throughout the experiment. Figure 26 shows the learning effect trend. Initially optimal NMI selection was around 63 percent; it steadily increased to 77 percent by round 25. Since the trend did not level off by round 25, it appears that a greater number of individuals would select optimal combinations of NMIs if either the experiment was to progress or if individuals were given more detailed instructions on how to pick NMI combinations.

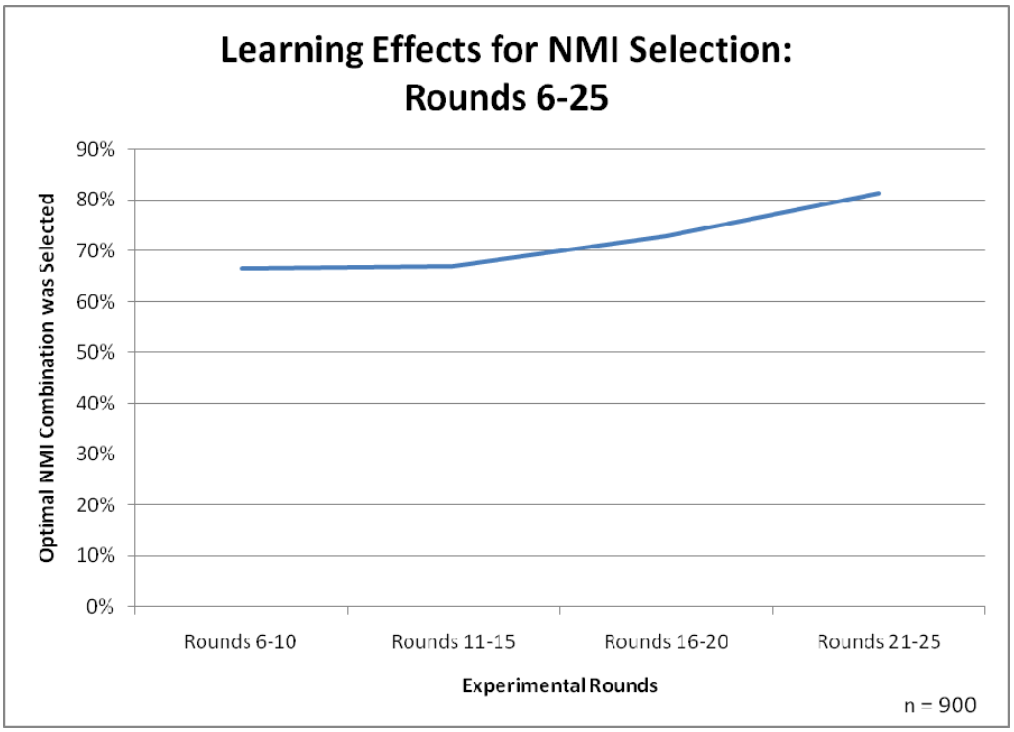

Figure 26. Learning Effects for NMI Selection: Rounds 6-25

b. Did Prior Experience With Similar Experiments Influence Results?

There were 13 participants, out of 49, who had experience with this type of experiment because of outside class room instruction or participation in another similar experiment. A comparison of those with known prior experience and those with no known prior experience was conducted to see if it influenced NMI selection. Results suggest that those with prior experience were not more likely to select the optimal NMI combination compared to those with no prior experience. Those with prior known experience and those without prior known experience performed almost identically.

4. Hypothesis Tests

a. Additive Trials

The first hypothesis test examines if the earlier additive trials were statistically different from the later additive trials. The null hypothesis is that trials 6-10 are statistically the same as trials 21-25 with a significance level of 0.05.

H_o: $P_{6\text{-}10} - P_{21\text{-}25} = 0$

H_a: $P_{6\text{-}10} - P_{21\text{-}25} \neq 0$

Where $P_{6\text{-}10}$ is the probability of selecting the optimal NMI combination in trials 6-10 and $P_{21\text{-}25}$ is the probability of selecting the optimal NMI combination in trials 21-25. The calculated p-value is 0.0004 and less than the alpha (0.05); therefore, we reject the null hypothesis and accept the alternative. The earlier additive rounds are statistically different from the later additive rounds. The likely reason for the large change from the earlier to later rounds can be attributed to the significant learning effect.

b. Combinatorial Trials

The second hypothesis test examines if the earlier combinatorial trials were statistically different from the later combinatorial trials. The null hypothesis is that trials 11-15 are statistically the same as trials 16-20 with a significance level of 0.05.

H_o: $P_{11\text{-}15} - P_{16\text{-}20} = 0$

H_a: $P_{11\text{-}15} - P_{16\text{-}20} \neq 0$

Where $P_{11\text{-}15}$ is the probability of selecting the optimal NMI combination in trials 11-15 and $P_{16\text{-}20}$ is the probability of selecting the optimal NMI combination in trials 16-20. The calculated p-value is 0.1811 and greater than the alpha (0.05); therefore, we fail to reject the null hypothesis. The earlier combinatorial rounds and later combinatorial rounds are statistically the same.

c. Comparing Additive and Combinatorial

The third hypothesis test examines if the additive trials were statistically different from the combinatorial trials. The null hypothesis is that the additive trials are statistically the same as the combinatorial trials with a significance level of 0.05.

H_o: $P_a - P_c = 0$

H_a: $P_a - P_c \neq 0$

Where P_a is the probability of selecting the optimal NMI combination in the additive trials and P_c is the probability of selecting the optimal NMI combination in the combinatorial trials. The calculated p-value is 0.1815 and greater than the alpha (0.05); therefore, we fail to reject the null hypothesis. The additive trials and the combinatorial trials are statistically the same.

D. BID RESULTS

The next part of the experiment asked participants to submit a bid to Firm A with only one goal: to maximize the total value of their compensation. By looking at the respective bids, we can evaluate how individuals bid in the discriminatory or uniform auction formats, how individuals

reacted to NMIs with combinatorial values, what type of problems individuals encountered, and the potential cost savings.

Firm B's salary offers were randomly generated and were different for each individual for each round. Similar to the NMIs by themselves, the individual bids have little meaning by themselves. A meaningful metric is the actual bid as a percentage of the optimal bid for each round. Recall from Chapter III that the optimal bidding strategy for a uniform, second-price auction is to bid equal to one's reservation wage. In this experiment, the individual's optimal bid under uniform pricing is either the offer from Firm B (if no NMIs were offered or none were selected) or Firm B's offer minus the combined value of selected NMIs. However, in a discriminatory, first-price auction it is optimal to bid above one's reservation wage (or above one's reservation wage minus the value of selected NMIs). Thus, the calculations for the following analysis comparing submitted bid request to the optimal request have already been adjusted for the different optimal bidding strategies under the two different pricing rules.

Using the metric of actual over optimal creates an easy measure to see how close subjects came to bidding optimally. A value of 100 percent means that the subjects were bidding on average optimally. A value less than or greater than 100 percent means that subjects were bidding on average below or above the optimal value, respectively.

1. Discriminatory Auction

a. Submitted Bid Request vs. Optimal Bid Requests

Figure 27 illustrates how closely individuals bid relative to the optimal bid; 100 percent represents an optimal bid. It appears that in the initial rounds subjects were slightly over bidding but adjusted their bidding strategy in the later rounds. Also, there was a noticeable dip in the first five combinatorial rounds; this could reflect learning as participants determine how to optimally reduce their bid in relation to the combined value of the NMIs chosen. Important to note, the overall average was 99.6 percent meaning that for all 30 trials individuals on average bid optimally.

The rounds which were classified as complex appeared to have induced lower than optimal bidding. Interesting to note is that those with experience tended to under bid in the discriminatory auction. This might be due to the fact that prior experience was primarily with uniform auction mechanisms. As mentioned earlier, in a uniform-price auction it is optimal to bid the reservation wage (Firm B’s offer) minus the combined value of any NMIs selected, but in a discriminatory auction it is optimal to bid above this amount.

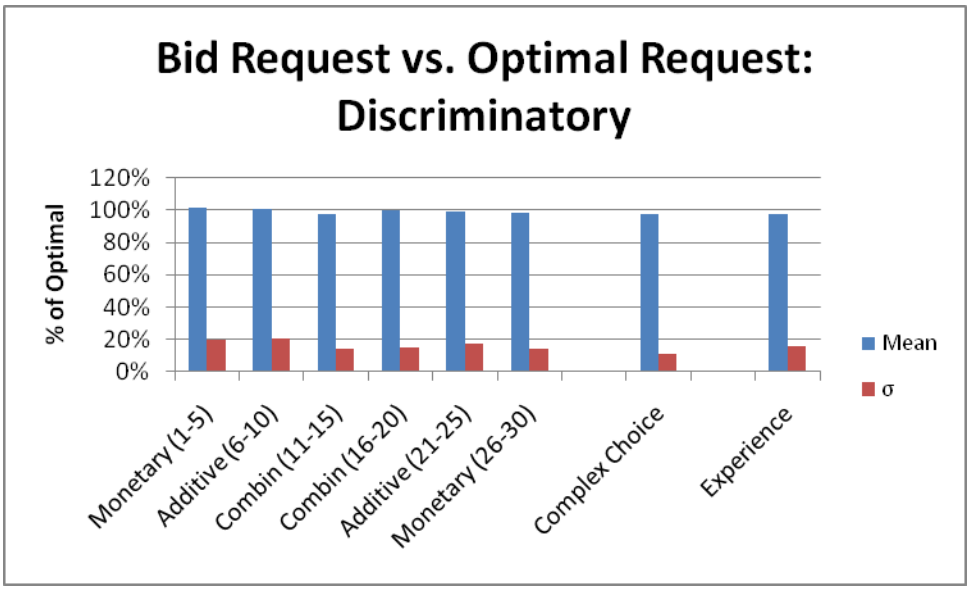

Figure 27. Bid Request vs. Optimal Request: Discriminatory

Figure 28 illustrates the spread of discriminatory bids as ratio of actual bid to optimal bid. Most bids were close to the optimal bid as reflected by a ratio of one; however, it appears the bidding never stabilizes to one.

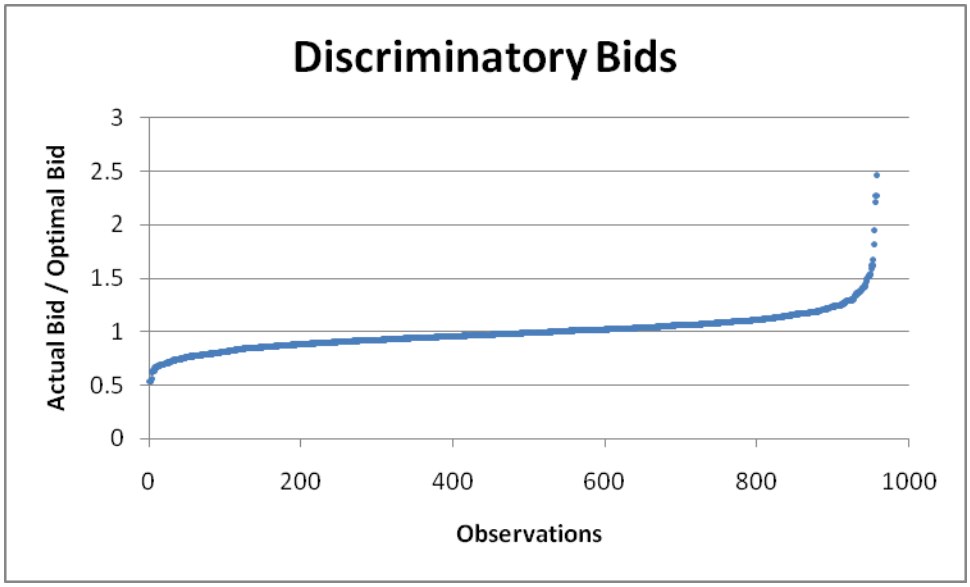

Figure 28. The Spread of Discriminatory Bids

b. Hypothesis Tests

Additional hypothesis tests examine if the earlier trials were statistically different from the later trials; hypothesis tests were conducted for the monetary, additive, and combinatorial discriminatory-price rounds. The null hypotheses are that the earlier five trials are statistically the same as the later five trials using the same treatment. The significance level of 0.05 was used to accept or reject the null hypothesis. The letter D in the notation below represents the average for the discriminatory trials annotated in subtext.

Monetary Trials:

H_o: $D_{1\text{-}5} - D_{26\text{-}30} = 0$

H_a: $D_{1\text{-}5} - D_{26\text{-}30} \neq 0$

The calculated p-value is 0.0396 which is less than the alpha (0.05). As a result we reject the null hypothesis in favor of the alternative: the means of the earlier and later trials are statistically different, indicating some learning in the monetary discriminatory price auction trials.

Additive Trials:

H_o: $D_{6\text{-}10} - D_{21\text{-}25} = 0$

H_a: $D_{6\text{-}10} - D_{21\text{-}25} \neq 0$

The calculated p-value is 0.3374 which is greater than the alpha (0.05). As a result we cannot reject the null hypothesis, the means of the first five additive NMI value trials and the last five additive trials were statistically the same.

Combinatorial Trials:

H_o: $D_{11\text{-}15} - D_{16\text{-}20} = 0$

H_a: $D_{11\text{-}15} - D_{16\text{-}20} \neq 0$

The calculated p-value is 0.0755 which is greater than the alpha (0.05). As a result we cannot reject the null hypothesis, the means of first five combinatorial NMI value trials and the second five trials are statistically the same.

c. Actual Outcome vs. Optimal Outcome

After the bids were submitted and individuals were either retained by Firm A or let go to Firm B, we can analyze how close the actual results are to the best case scenario (assuming everyone bid optimally) in terms of employee value and employer cost. As shown in Figure 29, the actual outcomes in the rounds with NMIs (rounds 6 – 25) appear to be closer to 100 percent, which is optimal, than the rounds with purely monetary bonuses. Overall, however, value and cost outcomes appear to be approximately 95 percent of the optimal outcome.

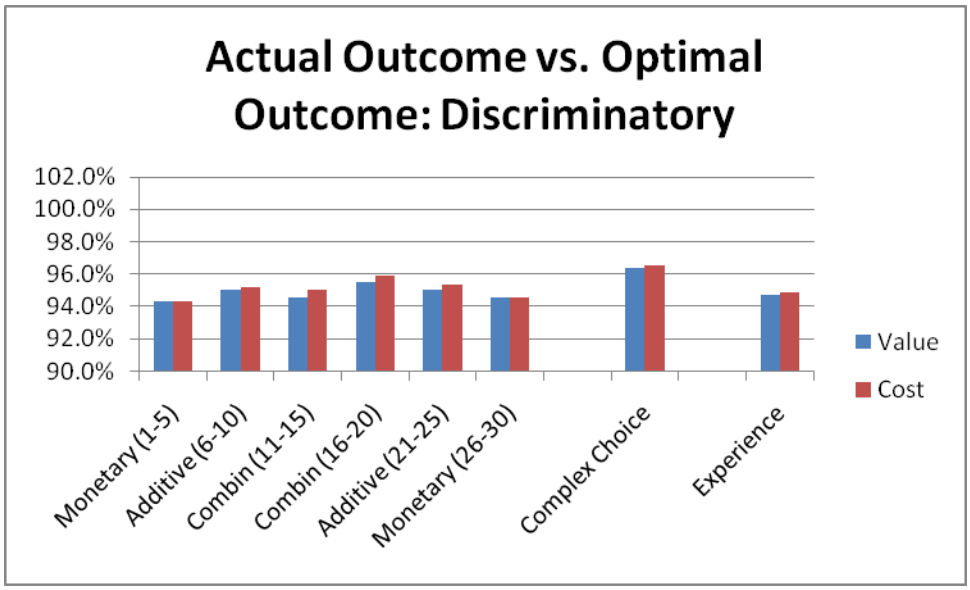

Figure 29. Actual Outcome vs. Optimal Outcome: Discriminatory

d. Value vs. Cost

When comparing the ratios of individual value and cost to retain, the discriminatory-price CRAM observations generated 94.8 percent of the employee value achieved with perfectly optimal bidder behavior, while incurring 95.1 percent of the employer cost associated with such optimal behavior. While the discriminatory auction was technically cheaper because the cost ratio was less than 100 percent, the value was lower as well meaning individuals could have gained more value.

e. Retention Errors Observed

If subjects make poor NMI choices or poor cash bid submissions, there is the potential for a retention error. The error is not due to the auction mechanism design, it is due to the decision made by an individual in

a particular auction round. There are three specific errors that are interesting to consider.

Table 3. Retention Errors: Discriminatory

Retention Errors Discriminatory			
	Firm B's Offer	Firm A Cutoff	
Inefficient Retention	100,000	80,000	
	Bid	Result	
Optimal bid *	110,000	over cutoff, therefore get 100,000 and go to Firm B	
Equiviant to optimal	>80,000	over cutoff, therefore get 100,000 and go to Firm B	
Error, not optimal	<80,000	under cutoff, therefore get bid amount and stay with Firm A	
	Firm B's Offer	Firm A Cutoff	
Inefficient Separation	80,000	100,000	
	Bid	Result	
Optimal bid *	90,000	under cutoff, therefore get 90,000 and stay with Firm A	
Equiviant to optimal	<100,000	under cutoff, therefore get bid amount and stay with Firm A	
Error, not optimal	>100,000	over cutoff, therefore get 80,000 and go to Firm B	
Involuntary Retention			
Optimal outcome	Value received in either Firm A or B was optimal in relation to bid		
Error, not optimal	Stayed with Firm A and total value received is less than Frim B's offer		
*Adjusted for discriminatory auctiona and Includeds costs for selected NMIs			

Table 3 provides an example of each type of error. For simplicity of illustration, the table illustrates each type of error within a monetary-incentive retention auction; however, these errors are also factors (even more so) in the presence of NMI offerings.

The first type of error is one of inefficient retention. An inefficient retention error occurs when an individual is retained by Firm A but was not one of the 50 least expensive employees to retain. The individual's minimum cost to retain (factoring in his reservation wage as well as his NMI values, if NMIs are offered) was among the top half of the employees bidding, meaning some other employee with a lower true cost to retain was separated.

This lower-cost-but-separated employee would have been willing to retain for a compensation package of lower cost than what was offered to the inefficiently retained employee, reducing the overall cost to Firm A.

The second type of error is an inefficient separation error. This is seen when an individual's true minimum cost to retain was among the 50 lowest, but he was nonetheless separated to Firm B. If a low cost individual overbids the optimal salary request, for example, and consequently exceeds Firm A's cutoff, he would be separated to Firm B, and some other employee with a higher true minimum cost to retain would take his place at Firm A. As with inefficient retention, inefficient separation means that there is a lower-cost-but-separated employee who would have been willing to retain for a compensation package of lower cost than what was offered to an inefficiently retained employee. Both inefficient retention and inefficient separation are errors which increase Firm A's cost (although perhaps only marginally).

Whereas the first two errors were defined from the perspective of the employer (Firm A), the third type of error, involuntary retention, is defined from the perspective of the employee. An employee is involuntarily retained whenever he is retained by Firm A and receives a compensation package whose total value is less than his reservation value (Firm B offer). In the military reenlistment context, an involuntary retention would refer to a situation in which a service member is offered reenlistment with a particular compensation package based on his NMI choices and cash bid but, in hindsight, the

service member decides he would rather separate instead. Such errors are obviously problematic from a force-management perspective, because too many such errors might cause the military service to undershoot its retention goals. Note that most cases of involuntary retention are also cases of inefficient cases, but this is not always the case. In particular, a service member could be retained involuntarily but not inefficiently, and vice versa.

Figure 30 illustrates the frequency of each type of retention error in the discriminatory-price CRAM observations. In rounds one through five the number of errors were slightly higher than in the later rounds. This could be attributed to individuals learning how the mechanism works, in the later rounds errors appeared to decrease slightly. Inefficient retentions and separations also seem to track together, suggesting that individuals bid inappropriately over and under the cutoff value almost equally. Rounds with NMIs characterized as complex choices do not have a higher error rate. Those individuals with past auction mechanism experience appear to have essentially the same error rates as the rest of the sample. As mentioned earlier this is likely reflects that most of the individuals with experience only had experience with second-price (uniform) price auctions, which does not provide experience with discriminatory price auctions.

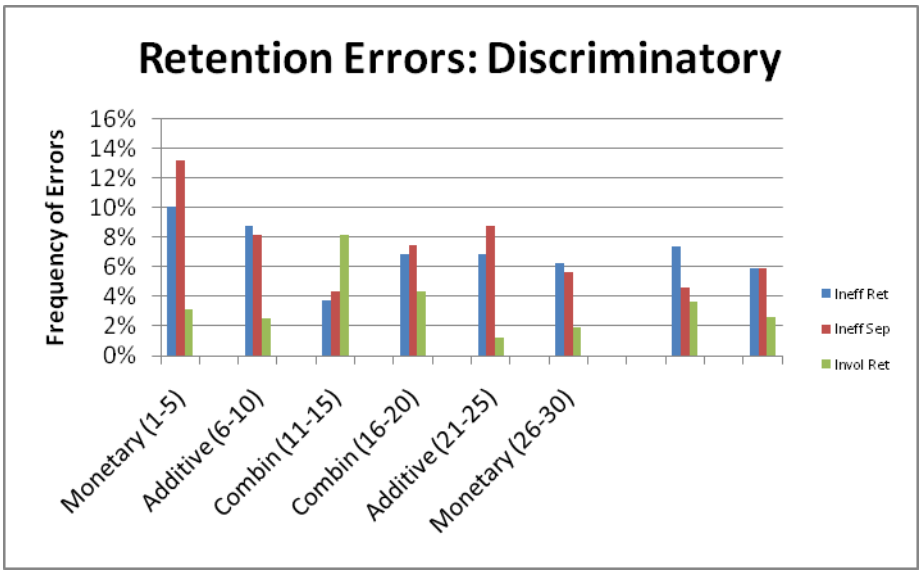

Figure 30. Retention Errors: Discriminatory

f. Cost Savings as a Result of Using NMIs

The discriminatory-price CRAM with additive-value or combinatorial-value NMIs provided a potential savings of 16 percent over a purely monetary auction mechanism. Cost savings is solely attributed to the chosen NMIs, and it is directly related to the value gained verses the cost of the NMIs received. While there was a cost savings of 16 percent, there was also less value gained by the individuals.

It should also be noted that the cost of the NMIs in this experiment generally averaged around ten percent in relation to the outside salary offer (reservation value). Therefore, even if all individuals chose the optimal combinations of NMIs, the savings due to incorporating NMIs would not significantly increase given the costs and values used in this experiment. This information is provided to show that the potential cost savings from incorporating NMIs could be even greater, as survey data indicates that many individuals value NMIs very highly relative to cash

retention incentives (with some NMI values even more than 100 percent of the required cash retention incentive).

2. Uniform Auction

a. Submitted Bid Request vs. Optimal Bid Requests

Figure 31 shows that on average individuals in the first ten rounds bid over the optimal amount, where the optimal bid is the actual reservation price. As the experiment progressed, overbidding decreased to just over 100 percent of the optimal bid. The overall average was 104.5 percent meaning that individuals were consistently over bidding throughout all the trials. The rounds that were considered to be complex choices appear to be no different than the other rounds. Those with experience bid differently in the uniform price auctions than those without experience. Shown in the last column in Figure 30, individuals with known experience bid consistently optimally, 100 percent of the optimal bid.

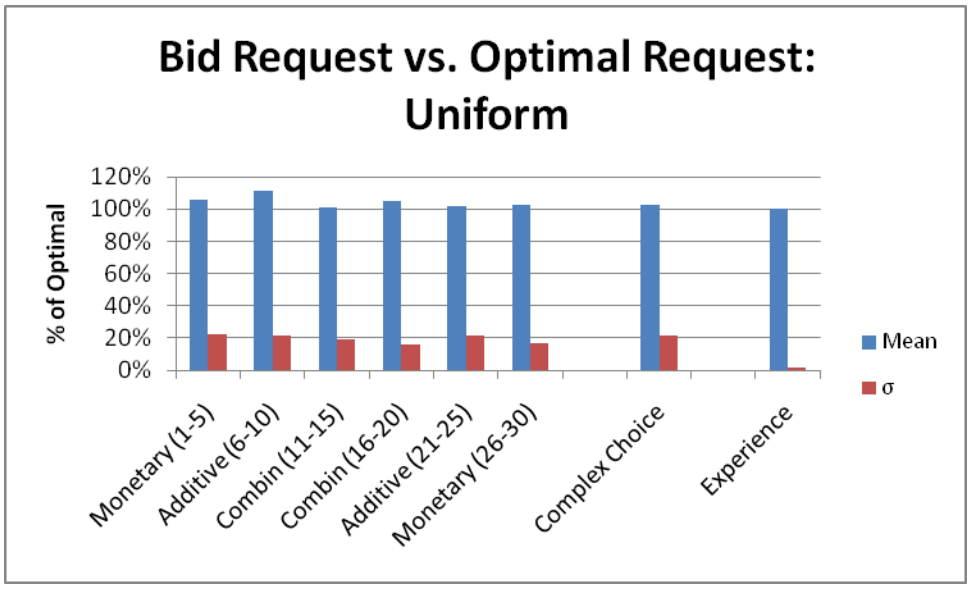

Figure 31. Bid Request vs. Optimal Request: Uniform

Figure 32 illustrates the spread of uniform price bids as a ratio of actual vs. optimal bid. Unlike the discriminatory trials, the uniform bidders do appear to level off at one, reflecting a large number of optimal bids. This suggests that many participants were continuously bidding optimally.

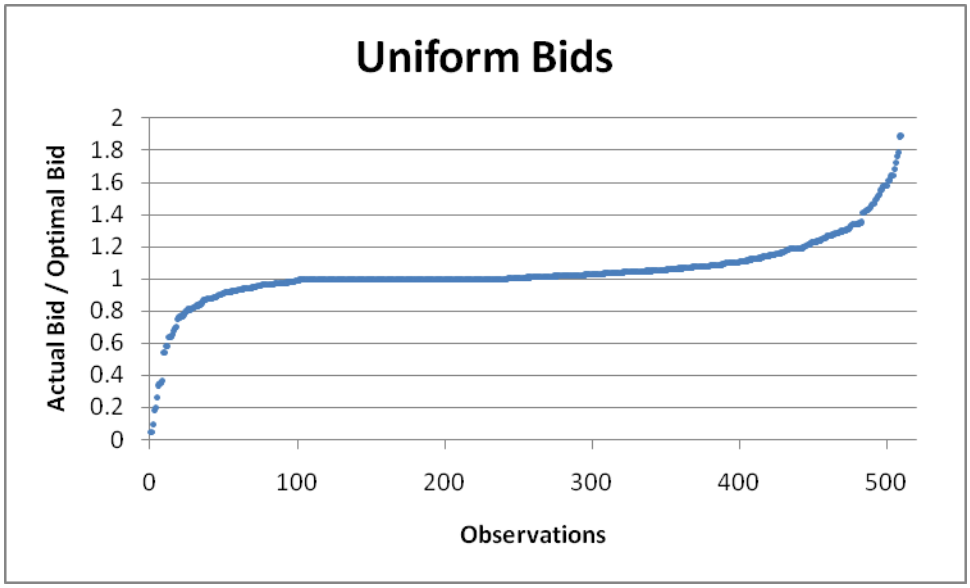

Figure 32. The Spread of Uniform Bids

b. Hypothesis Tests

Hypothesis tests to examine if the earlier trials were statistically different from the later trials were conducted for the uniform price monetary, additive, and combinatorial rounds. The null hypotheses are that the earlier five trials are statistically the same as the later five trials using the same treatment. The significance level of 0.05 was used to accept or reject the null hypothesis. The letter U in the notation below represents the average for the uniform trials annotated in subtext.

Monetary Trials:

H_o: $U_{1\text{-}5} - U_{26\text{-}30} = 0$

H_a: $U_{1\text{-}5} - U_{26\text{-}30} \neq 0$

The calculated p-value is 0.3654 which is greater than the alpha (0.05). As a result we cannot reject the null hypothesis; the mean of the first five trials in the monetary uniform price auction is statistically the same as the mean of the last five trials.

Additive Trials:

H_o: $U_{6\text{-}10} - U_{21\text{-}25} = 0$

H_a: $U_{6\text{-}10} - U_{21\text{-}25} \neq 0$

The calculated p-value is 0.0070 which is less than the alpha (0.05). As a result we reject the null hypothesis in favor of the alternative. The means from the first five trials are statistically different than the means for the later five trials for additive NMI values in the uniform price auction. This indicates some learning took place between the early and later bidding rounds.

Combinatorial Trials:

H_o: $U_{11\text{-}15} - U_{16\text{-}20} = 0$

H_a: $U_{11\text{-}15} - U_{16\text{-}20} \neq 0$

The calculated p-value is 0.1395 which is greater than the alpha (0.05). As a result we cannot reject the null hypothesis; in the uniform price auction, the means of the first five combinatorial NMI value trials and the second five trials are statistically the same.

c. Actual Outcomes vs. Optimal Outcomes

Once the bids were submitted and individuals were distributed to their respective firms, we can compare the actual outcomes and optimal outcomes in terms of employee value and employer cost, as shown in Figure 33. The results show that the actual outcomes are consistently 99 percent of the optimal value and cost outcomes throughout the experiment. This suggests that the uniform price CRAM mechanism produces outcomes very close to the optimum solution.

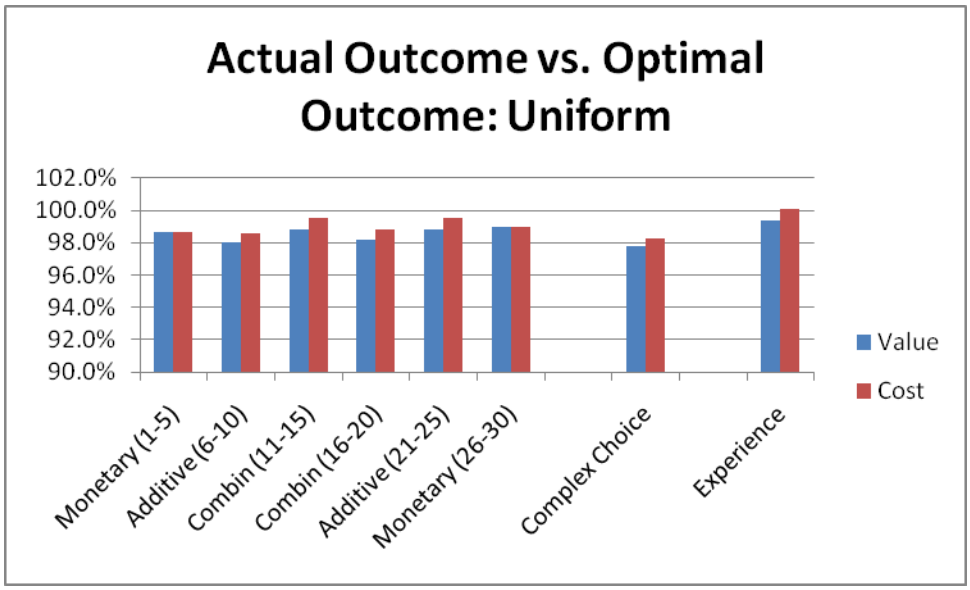

Figure 33. Actual Outcome vs. Optimal Outcome: Uniform

d. Value vs. Cost

When comparing the value vs. cost in the uniform price auction, the value was 98.6 percent and cost was 99.0 percent of the value and cost in the optimal solutions, respectively. The results indicate that individuals typically selected the optimal NMI combinations and optimal

monetary bid, resulting in costs which were near optimal; as a result, individuals capture most of the potential value available.

e. Retention Errors Observed

Mentioned earlier, retention errors are observed when individuals make sub-optimal NMI choices or cash bid decisions. Very similar to the discriminatory auction, the uniform auction has the same types of errors. Table 4 is identical to Table 3 shown for the discriminatory; however, it reflects a uniform-price auction. The most important thing to note is that now if a participant under or over bids but stays with Firm A, the bidder receives the cutoff value vice the bid submitted, affecting the impact of under or over bidding.

Table 4. Retention Errors: Uniform

Retention Errors Uniform			
	Firm B's Offer		Firm A Cutoff
Inefficient Retention	100,000		80,000
	Bid	Result	
Optimal bid *	100,000	over cutoff, therefore get 100,000 and go to Firm B	
Equiviant to optimal	>80,000	over cutoff, therefore get 100,000 and go to Firm B	
Error, not optimal	<80,000	under cutoff, therefore get 80,000 and stay with Firm A	
	Firm B's Offer		Firm A Cutoff
Inefficient Separation	80,000		100,000
	Bid	Result	
Optimal bid *	80,000	under cutoff, therefore get 100,000 and stay with Firm A	
Equiviant to optimal	<100,000	under cutoff, therefore get 100,000 and stay with Firm A	
Error, not optimal	>100,000	over cutoff, therefore get 80,000 and go to Firm B	
Involuntary Retention			
Optimal outcome	Value received in either Firm A or B was optimal in relation to bid		
Error, not optimal	Stayed with Firm A and total value received is less than Frim B's offer		
*Includeds costs for selected NMIs			

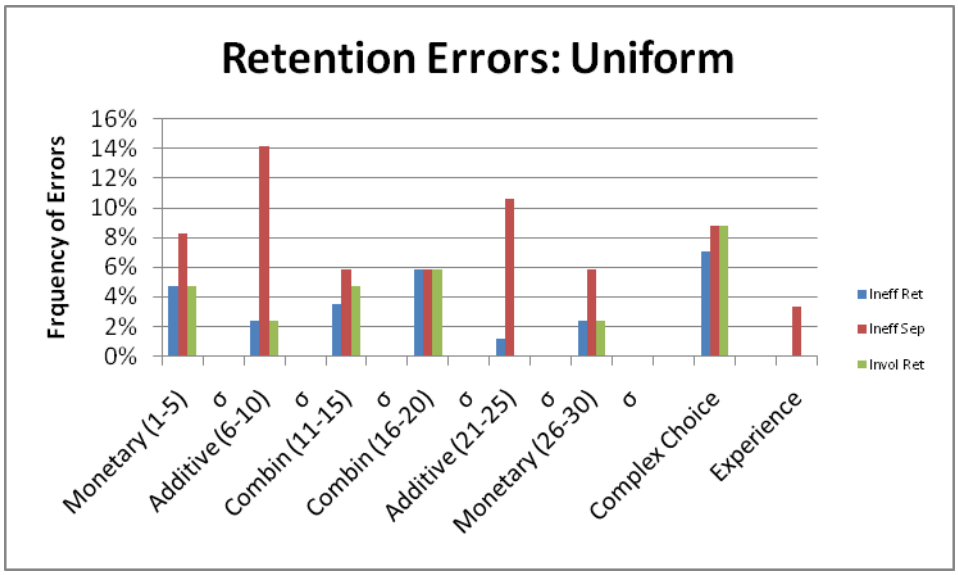

Figure 34. Retention Errors: Uniform

There were fewer inefficient retention errors (higher cost individuals inefficiently retained by Firm A) observed in the uniform-price CRAM compared to the discriminatory CRAM. Inefficient separation errors (lower cost individuals inefficiently separated to Firm B) appeared more prevalent in the additive rounds, as shown in Figure 34. These errors occurred when individuals overbid their optimal value, by doing this they exceeded the cutoff for Firm A and received Firm B's lower offer. If they submitted a bid equal to their reservation wage, they would have been retained and given a higher salary. In a uniform price auction, inefficient retention errors and involuntary retention errors won't necessarily coincide but often do because of the Firm A's cutoff value going to all retained employees (in fact, these errors will always coincide in the observations with monetary incentives alone). Those with known experience never had a type one or an involuntary retention error.

f. Cost Savings as a Result of Using NMIs

Using the uniform-price CRAM with additive-value and combinatorial-value NMIs resulted in a potential savings of two percent over the use of a purely monetary auction mechanism. As stated earlier, cost savings is solely attributed to the NMIs chosen. This experiment used NMIs which were valued on average at about ten percent of the reservation price provided; therefore, the potential cost savings within the experiment were relatively low.[63] In reality, individuals' value for NMIs may become very significant in relation to the cash equivalent, resulting in more value gained and more cost savings.

g. Was Participant Bidding Different Between the Discriminatory and Uniform Auctions?

A hypothesis test was conducted comparing the bidding averages in both the discriminatory and uniform auctions. The null hypothesis is the discriminatory and uniform means were statistically the same. The significance level used is 0.05.

H_o: D – U = 0

H_a: D – U ≠ 0

The calculated p-value is 0.0000 which is less than the alpha (0.05). Therefore, we must conclude that the discriminatory- and uniform-price auction means are statistically different.

[63] Random number generators were used to determine reservation prices (normally distributed; $50,000-250,000), NMI values (normally distributed; $0-$25,000), and NMI costs (function of NMI values, normally distributed; 0.25 – 1.25).

E. CHAPTER SUMMARY

A review of the NMI bids shows that individuals pick the optimal NMI combination 70 percent of the time. There was also a significant learning effect from the earlier rounds to the later rounds of a similar treatment. The bids submitted in both the discriminatory and uniform auctions suggest that individuals understand the value of NMIs and appropriately adjusted their bids.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

The current SRB program has largely accomplished its objectives, enabling the military services to meet their retention goals, but its weaknesses are becoming more apparent. The Combinatorial Retention Auction Mechanism (CRAM) has the potential to correct the known weaknesses and serve as a powerful future tool in shaping military manpower. The use of non-monetary incentives (NMIs) is a large component of the CRAM and potentially provides individuals with greater value while saving the military services money. Understanding how individuals view and select NMIs will undoubtedly be important for implementing a CRAM type SRB system.

1. Primary Research Question Answered

The findings in the research suggest individuals select the optimal NMIs about 70 percent of the time using the CRAM retention approach. There was a significant learning effect observed in comparing the earlier and later rounds; in the later rounds, individuals selected the optimal NMI combinations 81 percent of the time. Independent NMIs, whose values were purely additive, were chosen correctly 74 percent of the time. The combinatorial NMIs, with super- and sub-additive values, were selected correctly 70 percent of the time. The results suggest that many people understood combinatorial NMIs and chose the combination which produced the greatest surplus (value – cost).

2. Secondary Research Questions Answered

Individuals do appear to make rational decisions when faced with numerous NMI choices. This experiment only looked at two NMIs, which resulted in only four potential NMI allocations. Each individual had to look at the four possible combinations and select the one which created the greatest value. Of the four options, individuals were consistently able to pick the best one. It should be noted that by adding NMIs the choices increase exponentially. Three NMIs result in eight potential outcomes and five NMIs result in 32 potential outcomes. With a greater number of choices, it may be challenging for individuals to make the optimal choice. However, this research shows that most individuals will select combinations which at least approximate, if not equal, the optimal choice.

When comparing the uniform and discriminatory-price CRAM variations, significant differences in bidding were noticed. Those participating in the discriminatory price auction appeared to consistently underbid their optimal salary request, even with NMI combinations chosen, resulting in retention errors and reducing their earned value. In the uniform price auctions, individuals appeared to bid closer to their optimal salary request, resulting in more optimal outcomes.

More importantly, the results paralleled other combinatorial auction research. Stephen Rassenti stated that:

> The experimental results suggest that: (a) the procedures of the mechanism are operational, i.e., motivated individuals can execute the required task with a minimum of instruction and training; (b) the extent of demand under

> revelation by participant is not large, i.e., allocative efficiencies of 98-99 percent of the possible surplus seem to be achievable over time with experienced bidders.[64]

The experiment conducted for this thesis produced similar results: participants were able to make rational and efficient decisions based on relatively limited instructions. Participants were only told how the mechanism operated, not optimal bidding strategies. With the incorporation of NMIs, participants were still bidding rationally and creating efficiencies near 99 percent in a uniform-price combinatorial auction, which is similar to Rassenti's results.

3. Other Research Findings

The ability to look at those with experience separately from those without prior experience resulted in significant findings. Those participants with prior experience were typically experienced with the uniform price auction mechanism through classroom instruction or other presentations about the research. The results of this knowledge were apparent in the uniform-price CRAM observations, when every experienced participant bid optimally. However, when those experienced participants participated in a discriminatory price auction, they performed poorly because they used the wrong bidding strategy. The important aspect of these findings is that those who were given some additional instructions, explaining how the systems works and the truth revealing nature of a uniform price auction, consistently performed

[64] Stephen J. Rassenti, Vernon L. Smith, and Robert L. Bulfin, ("A Combinatorial Auction Mechanism for Airport Time Slot Allocation," *Bell Journal of Economics,* 12 (1982): 404-417.

optimally. Building off of this knowledge, instructions play a key role in the success of using an auction mechanism in a real world setting.

B. RECOMMENDATIONS FOR FUTURE STUDY

Introducing a uniform-price sealed-bid auction mechanism into the military SRB program would be an improvement and dramatic change from the current system. Further experiments are necessary before making a full or partial implementation. Building on past research, including this thesis, the next phase of experiments should begin to actually have participants bid against each other. All of the prior experiments, including this one, used a computer program and random numbers to determine the salary offers and the cutoff for Firm A; participants were competing against the computer. Future experiments should have participants actually competing with their physical neighbors to see if expected results match the actual results.

Another topic of interest is the instruction provided. Since those with experience bid consistently differently than those without experience, it would be important to conduct studies to see how a group would bid if they were told the optimal bidding strategy.

The use of NMIs is a critical component to the CRAM and raises questions about the best way to present information to the bidders. As the number of NMIs increases, the ability to find and make the optimal choice becomes increasing complex. It is important to find the best way to present the NMI choices and a mechanism which

allows individuals to see all the various combinations allowing them to make the best decision.

The ultimate goal would be to apply the CRAM to an actual group of military service members in competition for an actual bonus. It is a large goal, but it is well worth the effort. The military services would be at the leading edge of manpower utilization; efficiently using tax dollars, focused and precise force management, and including monetary and non-monetary incentives, all while giving service members greater options and potentially greater value.

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APPENDIX A. REVENUE EQUIVALENCE

For revenue equivalence, assume officers are risk-neutral.

Each officer assumes they are the median-bidder of the acceptable bids (lowest 75).

They will assume the higher bids are uniformly distributed over the distribution between their opportunity cost and the upper bound of the uniform distribution (common knowledge to all officers).

They will set their bid in a first price auction to beat the first rejected bid.

This generates the set of first-price bids illustrated above.

With N officers (100), m winners (75) and opportunity cost distributed uniformly between C_l and C_h (0 -- 60), officer (i) with opportunity cost C_i will submit a bid B_i given by:

$$B_i = C_i + \left(\frac{\left(m+1/2\right)}{N-\left(m+1/2\right)+1} \right) * (C_h - C_i)$$

In this example, 38 sailors will submit bids below the first rejected bid in the second-price auction, saving the military $168,000 in surplus value; 37 sailors will submit bids above the first rejected bid in the second-price auction, costing the military $168,000 in surplus value for these officers.

The net effect is to redistribute surplus value from low to high opportunity cost sailors, leaving the total military cost unaffected; hence, revenue equivalence.

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APPENDIX B. REQUEST FOR VOLUNTEERS

REQUEST FOR PAID VOLUNTEERS

Fellow NPS Students,

I am seeking paid volunteers to participate in a decision making experiment. The experiment is in support of a thesis, investigating ways to improve military compensation and retention.

What: Participants will use a computer and input responses based on information provided. Detailed instructions will be given and it will be conducted in a stress-free environment. The total experiment will take less than 2 hours. Volunteers will get paid based on decisions made during the experiment; average earnings will be between $20-$30.

When: Feb 4 (Thur) @ 1300, or Feb 5 (Fri) @ 1200, or Feb 5 (Fri) @ 1500

Where: NPS, Ingersoll computer lab (Ing-224)

Who: Open to all NPS Students

Why: To assist a fellow student with research and get paid

How: If you are interested, please e-mail me (kphahn@nps.edu). Tell me what times you prefer and provide a 1st and 2nd choice incase a session becomes filled. I will respond to you, confirming your participation and time.

Thank you for your time.

Very Respectfully,
Capt Kyle Hahn
NPS Student
Manpower Systems Analysis

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APPENDIX C. INSTRUCTIONS

A. EXPERIMENT INSTRUCTIONS

COMBINATORIAL RETENTION AUCTION MECHANISM (CRAM)

MENU-STYLE / UNIFORM PRICING & DISCRIMINATORY PRICING

EXPERIMENT INSTRUCTIONS

You are about to participate in an experiment in labor market decision making. If you have not done so already, please complete the experiment participant registration form that should be on your computer screen. As noted on your screen, please do not click the “proceed” button until you are instructed to do so.

We will start today with an initial instruction period that should take about 30 minutes. There will also be several shorter additional instruction periods during the experiment. The actual experiment itself should take approximately 60 minutes, and the entire process should be complete no later than _____ as promised.

You will be paid for your participation in cash at the end of the experiment. Different participants may earn different amounts. What you earn depends partly on the decisions you make and partly on certain probabilistic events that will be explained during these instructions. Although there are several of you participating in this experiment simultaneously, your earnings from the experiment will <u>not</u> depend on the decisions made by any of the other participants. This experiment does not involve any interaction between participants.

The entire experiment will take place through the computer terminals in front of you, and your primary actions will involve using the mouse to click on boxes or buttons and using the keyboard to enter numeric answers. It is important that you not talk or in any way try to communicate with or observe the actions of other participants during the experiment.

As noted previously, we are starting with a somewhat lengthy instruction period. During the instruction period, you will be given a complete description of the experiment and you will be introduced to the type of decisions you will be asked to make during the experiment. If you have any questions during the instruction period, raise your hand and your question will be answered so that everyone can hear. If any difficulties arise after the experiment has begun, raise your hand, and an experimenter will come and assist you.

The experiment itself will consist of 30 rounds. The instruction period will involve going through a practice round which is identical in structure 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. We will all go through the practice round together at the same pace.

Has everybody completed filling out the participant registration form on your computer screen? Okay, please go ahead and use the computer mouse to click on the button that says, “Proceed to Practice Round.”

PRACTICE ROUND – PRACTICE SURVEY A-F

You should now all be looking at a screen that says "Scenario Background" at the top left. As you can see, this screen contains an extensive description of the labor market scenario we are investigating in this experiment. During this practice round, I will read aloud all of the information that is written on your computer screen and you should read along.

During the actual experiment, all of the descriptive information that you see on your screen will also be provided each round, although you do not need to re-read the information each round. It is simply provided as a reference in case you would like to go back and review the scenario description.

I will now begin reading the description on your computer screen.

READ: Scenario Background – Salary Offer from Firm B

All of you should have the value of $150,000 in the white box on your screen for this practice round. During the actual experimental rounds, however, everybody will receive different annual salary offers from Firm B. In addition, you will be given a different offer from Firm B in each of the 30 rounds of the experiment. Now I will continue reading the description on your computer screen.

READ: Distribution of Salary Offers from Firm B – Salary Survey at Firm A

Before continuing, let me further illustrate how your employer and salary will be determined using the chart we

have given you titled “Salary Survey to Determine Employer and Salary.” [Show and explain slide]

READ: Your Salary Request to Firm A

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

For illustration purposes during this practice round, I would like each of you to type the amount $75,000 in the white box and then hit the enter key. After you have done so, you may click on the “Submit” button with the mouse.

PRACTICE ROUND OUTCOME – FIRM A

You should now all be looking at a screen that says “Results” at the top left. This is the screen that you will see if your salary request was among the 50 lowest of the 100 salary requests submitted, in which case you will be retained by Firm A.

I will now read the description on your computer screen.

READ: Results Retained by Firm A

If you arrive at this screen during the experimental rounds, you will have completed your task for the round, however you must wait until everybody else has finished the

round before proceeding. It is very important that we all proceed through the experiment at the same pace, because there will be changes to the procedure in later rounds which I must explain to all of you at the same time when you all arrive at that point of the experiment. Because all participants must proceed to each successive experimental round at the same time, you will need to wait until I instruct you to do so before clicking the "Proceed" button.

During this practice round, however, we will go back to the beginning to see what can happen if you submit a different salary request in the second salary survey. Therefore, please go ahead and click the "proceed" button now.

PRACTICE ROUND OUTCOME – FIRM B

What we have just reviewed is what will happen and what you will see if your salary request is among the 50 lowest of the 100 salary requests submitted, in which case you will be retained by Firm A. We will now illustrate what happens if your salary request is among the 50 highest of the 100 salary requests submitted.

Clicking on the "Proceed" button should have returned all of you to the original Practice Survey screen with the words "Scenario Background" at the top left. All of the information and dollar values on this screen are identical to what we saw previously. In particular, your salary offer from Firm B should once again be $150,000.

Please now scroll to the bottom of this screen where it says:

What annual salary do you request from Firm A?

To illustrate what happens if your salary request is among the 50 highest of the 100 salary requests submitted, I would like each of you to type the amount $175,000 in the white box and then hit the enter key. After you have done so, you may click on the "Submit" button with the mouse.

You should now all be looking at a screen that says "Results" at the top left. This is the screen that you will see if your salary request was among the highest 50 of the 100 salary requests submitted, in which case you will not be retained by Firm A and will be employed by Firm B at the salary offered previously.

I will now read the description on your computer screen.

READ: Results Not Retained by Firm A - Distribution of Salary Requests to Firm A

Please note that the lowest, highest, and 50th highest salary request figures here are identical to the ones shown previously. This is done for illustrative purposes only, however, so keep in mind that these figures will be change for you in each round of the experiment and will be different for each participant each round.

Now I will continue reading the description on your computer screen.

READ: Your Employer and Salary

If you arrive at this screen during the experimental rounds, you will have completed your task for that round, however you must wait until everybody else has finished the round before proceeding. All participants will need to proceed to the next experimental round at the same time,

therefore you will need to wait until I instruct you to do so before clicking the “Proceed” button.

CONCLUSION

Before we all click the “Proceed” button at the bottom of the screen to start the actual experimental rounds, are there any questions before we begin?

Remember that, on the initial salary survey screen, you will determine the annual salary that you would like to request from Firm A based on the information given, and you will then type your request in the white box at the bottom of this page. You will be free to click the “Submit” button whenever you are satisfied with the salary request you have entered. When you reach the “Results” screen, however, please do not click the “Proceed” button until instructed to do so.

Please click the “proceed” button and begin round 1 of the experiment. Thank you.

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APPENDIX D. EXPERIMENTS

A. UNIFORM

1. Cash Bid

Scenario Background
You are 1 of 100 employees currently working for Firm A.
Your only other potential employer is Firm B.
You have no particular preference for Firm A or for Firm B.
You can easily switch employers at no cost or inconvenience to you.
Your only goal is to maximize the value of your annual compensation.

Downsizing at Firm A
Firm A will be downsizing, and 50 of its 100 employees be will be laid off immediately.
After these one-time layoffs, however, employees will have the same level of job security at Firm A as at Firm B.

Employment Offer from Firm B
Firm B has offered to employ anybody who leaves Firm A.
If you leave Firm A now, you will work at Firm B immediately.
This standing offer of employment at Firm B applies whether you leave Firm A voluntarily or are laid off.

Salary Offer from Firm B
Firm B has presented a confidential annual salary offer to each employee currently working for Firm A.
The offer presented to each employee represents the annual salary that he/she will receive if employed by Firm B.
Firm B has offered different annual salary amounts to different Firm A employees.
Firm B has offered to pay you the following annual salary: $

Distribution of Salary Offers from Firm B
You do not know the salary amounts that Firm B has offered to other current employees at Firm A.
You know only that all of Firm B's salary offers are spread evenly over some range.
In other words, these salary offers are spread evenly between some lower bound & some upper bound.
You do not know the actual lower and upper bounds of the range of salary offers.
However, you do know that the salary offered to you by Firm B lies somewhere within this range of offers.
Thus, it likely that some of Firm B's salary offers to potential employees are higher than your offer above.
It is also likely that some of Firm B's salary offers to potential employees are lower than your offer.

Salary Survey at Firm A
The salary paid to any Firm A employee in previous years will have no influence on his/her future salary at Firm A.
Instead, the annual salary that Firm A will pay to each of its retained employees will be determined using a survey.
"Firm A is asking each of its 100 workers to specify the minimum annual salary that he/she would need to receive in order to remain with Firm A."
Firm A will then retain the 50 of its 100 employees who submitted the 50 lowest salary requests.
In other words, after collecting all 100 "salary requests" from its employees, Firm A will lay off the 50 employees who submitted the 50 highest salary requests.
Each of the 50 employees laid off will immediately begin working at Firm B at the salary previously offered.
The remaining 50 employees will work at Firm A.
All employees retained by Firm A will be paid the same salary, regardless of the salary they requested.
These retained employees will be paid the lowest salary that was requested among the 50 employees laid off
In other words, Firm A will pay all retained employees the 50th highest salary requested.
Note that this salary will be as high or higher than the salary requested by any of the 50 retained employees.

Your Salary Request to Firm A
You must now decide what annual salary to request from Firm A.
"Remember that if your request is among the highest 50 of the 100 salary requests submitted, you will be laid off from Firm A and will work for Firm B.
If your salary request to Firm A is among the 50 lowest requests, you will continue to work for Firm A and will receive an annual salary equal to the lowest salary requested among the 50 employees not retained.

Recall that Firm B is offering you: $

What annual salary do you request from Firm A:

Salary Request to Firm A:

You May Click Button Whenever You Are Satisfied With Your Salary Request Above.

a. Retained by Firm A

Results
Your salary request was among the 50 lowest requested, and you will therefore be retained by Firm A.

Distribution of Salary Requests to Firm A
The lowest annual salary request submitted to Firm A by one of its other current employees was: $
The highest annual salary request submitted to Firm A by one of its other current employees was: $
The 50th highest annual salary request submitted to Firm A by one of its current employees was: $
Your annual salary request to Firm A was: $

Your Employer and Salary
Since your salary request was among the 50 lowest requests submitted to Firm A, you will be retained by Firm A.
Your salary will be equal to the 50th highest salary request submitted to Firm A as given above.
Thus, your salary will be: $

The salary above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

b. Not Retained by Firm A

Results
Your salary request was among the 50 highest requested, and you will therefore not be retained by Firm A.
You will now be employed by Firm B.

Distribution of Salary Requests to Firm A
The lowest annual salary request submitted to Firm A by one of its other current employees was: $
The highest annual salary request submitted to Firm A by one of its other current employees was: $
The 50th highest annual salary request submitted to Firm A by one of its current employees was: $
Your annual salary request to Firm A was: $

Your Employer and Salary
Since your salary request was among the 50 highest requests submitted to Firm A.
You will not be retained by Firm A and will instead be employed by Firm B.
Your salary will be equal to the offer provided by Firm B.
Thus, your salary will be: $

The salary above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

2. Independent NMI Bid

Scenario Background
You are 1 of 100 employees currently working for Firm A.
Your only other potential employer is Firm B.
You have no particular preference for Firm A or for Firm B.
You can easily switch employers at no cost or inconvenience to you.
Your only goal is to maximize the total value of your annual compensation.
Your compensation may now include both monetary and non-monetary incentives.

Non-Monetary Incentives (NMIs)

A non-monetary incentive (NMI) is any benefit provided to an employee other than cash compensation.
Examples of NMIs include such benefits as:
-- Housing or education assistance,
-- Flexible work arrangements, and
-- Choice of a particular office, location, or position
Firm A is offering two potential non-monetary incentives which will be generically labeled NMI 1 and NMI 2.
In addition to his/her salary, each employee retained by Firm A will receive either:
(a) NMI 1 only.
(b) NMI 2 only.
(c) Both NMI 1 and NMI 2, or
(d) Neither NMI 1 nor NMI 2.
In fact, each employee retained by Firm A will choose which NMI or NMIs he/she would like to receive.
How these choices are made will be described in more detail below.

Your Value for Non-Monetary Incentives
Your values for each of the two NMIs offered by Firm A (and for both NMIs in combination) are as follows:

	Value
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

These amounts reflect your cash equivalent value for each NMI as well as the combination of both NMIs.
In other words, each NMI has the same value to you as the corresponding cash amount indicated above.
Put another way, you would rather receive the NMI than any cash amount less than the value indicated.
Conversely, you would rather receive any cash amount greater than the indicated value than receive the NMI.
Also, note that your value for both NMIs together is simply the sum of the two individual NMI values.
With the possibility of receiving NMIs, the total value of your annual compensation will now be the sum of:
(1) Your annual salary amount, plus
(2) Your value for any NMIs or combination of NMIs you receive
Recall that your actual cash earnings from this experiment are determined by this total value of your annual compensation, not by your salary alone.
Please also note that your NMI values will change in each round of the experiment.

The Distribution of NMI Values
Different employees value each NMI differently.
Some employees will value an NMI very highly while others will assign very little value to the very same NMI.
For each of the two NMIs offered by Firm A, employee valuations range between $0 and $25,000.
Moreover, the employee values for each NMI are spread evenly over this range.
Thus, you know that any other employee could value a particular NMI as little as $0 or as much as $25,000, with each value between those extremes being equally likely.

The Cost of Non-Monetary Incentives
Firm A must incur some cost to provide either NMI (or both NMIs) to one of its employees.
Firm A's cost of providing each of the two NMIs (or both NMIs in combination) is as follows:

	Cost
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

Note that Firm A's cost to provide both NMIs together is simply the sum of the two individual NMI costs.

Downsizing at Firm A
Firm A will be downsizing, and 50 of its 100 employees be will be laid off immediately.
After these one-time layoffs, however, employees will have the same level of job security at Firm A as at Firm B.

Employment Offer from Firm B
Firm B has offered to employ anybody who leaves Firm A.
If you leave Firm A now, you will work at Firm B immediately.
This standing offer of employment at Firm B applies whether you leave Firm A voluntarily or are laid off.

Salary Offer from Firm B
Firm B has presented a confidential annual salary offer to each employee currently working for Firm A.
The offer presented to each employee represents the annual salary that he/she will receive if employed by Firm B.
Firm B has offered different annual salary amounts to different Firm A employees.
Firm B has offered to pay you the following annual salary: $
Compensation at Firm B will consist of this monetary incentive alone.

Firm B employees will not receive any non-monetary incentives.

Distribution of Salary Offers from Firm B
You do not know the salary amounts that Firm B has offered to other current employees at Firm A.
You know only that all of Firm B's salary offers are spread evenly over some range.
In other words, these salary offers are spread evenly between some lower bound & some upper bound.
You do not know the actual lower and upper bounds of the range of salary offers.
However, you do know that the salary offered to you by Firm B lies somewhere within this range of offers.
Thus, it likely that some of Firm B's salary offers to potential employees are higher than your offer above.
It is also likely that some of Firm B's salary offers to potential employees are lower than your offer.

Determining Which Employees to Retain at Firm A
Firm A will determine which 50 employees to retain -- and how each retained employee will be compensated using a survey regarding requested compensation.
This compensation survey will now consist of two parts
(1) An NMI survey in which each employee identifies which NMIs he/she wants to receive if retained; and
(2) A salary survey in which each employee specifies the minimum annual salary that he/she would need to receive in order to remain with Firm A assuming that he/she would also receive the NMI(s) requested.
Firm A will calculate the total cost of each employee's compensation request as the sum of:
(1) The cost of any NMIs or combination of NMIs he/she requested in the NMI survey, plus
(2) The annual salary amount he/she requested in the salary survey.
The 50 employees who submit the 50 lowest-cost compensation requests will be retained by Firm A.
The 50 employees who submit the 50 highest-cost compensation requests will be laid off.
Each of the laid off employees will immediately begin working at Firm B at the salary previously offered.

Determining Compensation for Employees at Firm A
Note that the 50 employees retained by Firm A will likely receive different compensation packages, because they will have presumably requested different NMIs in the NMI survey.
Nonetheless, the compensation package (salary plus NMIs) received by each retained employee will have the same total cost to Firm A, regardless of the NMIs or salary requested.
In particular, each retained employee will receive a compensation package whose total cost is equal to the cost of the lowest-cost compensation request among the 50 laid-off employees.
In other words, each retained employee will receive a compensation package whose total cost is equal to the cost of the 50th highest-cost compensation request.
To illustrate, let us refer to the cost of this 50th highest-cost compensation request as the "cutoff cost."
Note that each of the 50 retained employees will have submitted a compensation request whose total cost was below this cutoff cost.
Recall that each retained employee will receive whichever NMI or NMIs he/she requested in the NMI survey.
The salary for each employee retained by Firm A will then be determined as follows:

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

Thus, each Firm A employee receives a salary equal to the cutoff cost minus the total cost of NMIs received.
Note that, while salaries may vary, the total compensation cost for all Firm A employees will be the same.
Also note that the salary received by each Firm A employee does not depend upon either:
(1) the actual salary amount he/she requested, nor
(2) his or her value for either or both of the NMIs.

NMI Survey at Firm A
Recall that the value (to you) and the cost (to Firm A) associated with the NMIs offered is as follows:

	Value	Cost
NMI 1	$	$
NMI 2	$	$
Both NMIs	$	$

Please now select which, if any, of the two NMIs you would like to receive if retained by Firm A.
In doing so, please recall that:
(1) If you are retained by Firm A, you will receive any NMI chosen,
(2) The total value of your compensation at Firm A increases by the value of each NMI (or combination) chosen,
(3) The cost of each NMI chosen will be added to your salary request when determining whether you will be retained by Firm A (i.e., whether your compensation request is among the 50 lowest-cost requests), and
(4) In exchange for each NMI chosen, the cost of that NMI will be subtracted from your salary if retained by Firm A.
Please choose by selecting the button(s) next to the NMI(s) offered.

NMI 1
NMI 2

The total value and cost associated with the NMI selections above is:

Total NMI value for you: $
Total NMI cost for Firm A: $

Salary Survey at Firm A
Firm A is further asking each of its 100 workers to specify the minimum annual salary that he/she would need to receive in order to remain with Firm A, given that he/she would also receive the NMI(s) requested if retained.
Recall that Firm B is offering you: $
Thus, knowing Firm B's offer & that you will receive the NMIs selected above (& the associated total NMI value) if you remain with Firm A, what annual salary do you request from Firm A in addition to the NMI(s) chosen?

Salary Request to Firm A:

Total Value and Cost of Your Compensation Request

Given your NMI and salary requests above, note that the total value and cost of your combined requests are:

Total value (to you) of your compensation request : $
Total cost (to Firm A) of your compensation request: $

You May Click Button Whenever You Are Satisfied With Your NMI and Salary Requests Above.

a. Retained by Firm A

Results
The total cost of your compensation request was among the 50 lowest-cost requests submitted to Firm A.
In other words, the total cost of your compensation request was below the "cutoff cost" among all requests.
Therefore, you will be retained by Firm A.

Distribution of Salary Requests to Firm A
The lowest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The highest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The 50th highest ("cutoff") cost of all compensation requests submitted to Firm A by one of its employees was: $
The total cost of the compensation request you submitted to Firm A was: $

Your Non-Monetary Incentives
Recall that the value (to you) and the cost (to Firm A) associated with the NMIs offered was as follows:

	Value	Cost
NMI 1	$	$
NMI 2	$	$
Both NMIs	$	$

Because you are to be retained by Firm A, you will receive any NMIs you requested in the compensation survey.
Thus, the NMIs included as part of your compensation at Firm A will be as follows:

	Received?
NMI 1	YES/NO
NMI 2	YES/NO

The total value and cost associated with the NMIs you will receive are as follows:

Total NMI value for you: $
Total NMI cost for Firm A: $

Your Salary
Recall that each Firm A employee receives a salary equal to the cutoff cost minus the total cost of NMIs received.
Thus, your salary is determined as follows:

Cutoff cost (i.e., 50th highest cost compensation request): $
Total cost of NMIs you will receive: $
Your annual salary at Firm A: $

Total Value of Your Annual Compensation
The total value of your annual compensation is therefore given by:

Annual salary: $
Total NMI value: $
Total compensation value: $

The total compensation value above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

b. Not Retained by Firm A

Results
The total cost of your compensation request was among the 50 highest-cost requests submitted to Firm A.
In other words, the total cost of your compensation request was above the "cutoff cost" among all requests.
Therefore, you will not be retained by Firm A and will now be employed by Firm B.

Distribution of Salary Requests to Firm A
The lowest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The highest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The 50th highest ("cutoff") cost of all compensation requests submitted to Firm A by one of its employees was: $
The total cost of the compensation request you submitted to Firm A was: $

Your Salary
As indicated, you will not be retained by Firm A and will instead be employed by Firm B.
Because Firm B does not offer NMIs, the total value of your compensation will be reflected in your annual salary.
Your salary will be equal to the amount previously offered to you by Firm B.
Thus, your salary will be: $

The salary above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

3. Combinatorial NMI Bid

Scenario Background
You are 1 of 100 employees currently working for Firm A.
Your only other potential employer is Firm B.
You have no particular preference for Firm A or for Firm B.
You can easily switch employers at no cost or inconvenience to you.
Your only goal is to maximize the total value of your annual compensation.
Your compensation may now include both monetary and non-monetary incentives.

Non-Monetary Incentives (NMIs)
A non-monetary incentive (NMI) is any benefit provided to an employee other than cash compensation.
Examples of NMIs include such benefits as:
-- Housing or education assistance,
-- Flexible work arrangements, and
-- Choice of a particular office, location, or position
Firm A is offering two potential non-monetary incentives which will be generically labeled NMI 1 and NMI 2.
In addition to his/her salary, each employee retained by Firm A will receive either:
(a) NMI 1 only.
(b) NMI 2 only.
(c) Both NMI 1 and NMI 2, or

(d) Neither NMI 1 nor NMI 2.
In fact, each employee retained by Firm A will choose which NMI or NMIs he/she would like to receive.
How these choices are made will be described in more detail below.

Your Value for Non-Monetary Incentives
Your values for each of the two NMIs offered by Firm A (and for both NMIs in combination) are as follows:

	Value
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

These amounts reflect your cash equivalent value for each NMI as well as the combination of both NMIs.
In other words, each NMI has the same value to you as the corresponding cash amount indicated above.
Put another way, you would rather receive the NMI than any cash amount less than the value indicated.
Conversely, you would rather receive any cash amount greater than the indicated value than receive the NMI.
Also, note that your value for both NMIs together is simply the sum of the two individual NMI values.
With the possibility of receiving NMIs, the total value of your annual compensation will now be the sum of:
(1) Your annual salary amount, plus
(2) Your value for any NMIs or combination of NMIs you receive.
Recall that your actual cash earnings from this experiment are determined by this total value of your annual compensation, not by your salary alone.
Please also note that your NMI values will change in each round of the experiment.

The Value of NMIs in Combination
The value to you from receiving both NMIs will now often not be equal to the sum of the two individual NMI values.
Sometimes, the value of the combination may be greater than the sum of the two individual NMI values.
At other times, the value of the combination may be less than the sum of the two individual NMI values.
In either case, the value of the combination may influence which NMI or NMIs (if any) you want to choose.

The Distribution of NMI Values
Different employees value each NMI differently.
Some employees will value an NMI very highly while others will assign very little value to the very same NMI.
For each of the two NMIs offered by Firm A, employee valuations range between $0 and $25,000.
Moreover, the employee values for each NMI are spread evenly over this range.
Thus, you know that any other employee could value a particular NMI as little as $0 or as much as $25,000, with each value between those extremes being equally likely.

The Cost of Non-Monetary Incentives
Firm A must incur some cost to provide either NMI (or both NMIs) to one of its employees.
Firm A's cost of providing each of the two NMIs (or both NMIs in combination) is as follows:

	Cost
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

Note that Firm A's cost to provide both NMIs together is simply the sum of the two individual NMI costs.

Downsizing at Firm A
Firm A will be downsizing, and 50 of its 100 employees be will be laid off immediately.
After these one-time layoffs, however, employees will have the same level of job security at Firm A as at Firm B.

Employment Offer from Firm B
Firm B has offered to employ anybody who leaves Firm A.
If you leave Firm A now, you will work at Firm B immediately.
This standing offer of employment at Firm B applies whether you leave Firm A voluntarily or are laid off.

Salary Offer from Firm B
Firm B has presented a confidential annual salary offer to each employee currently working for Firm A.
The offer presented to each employee represents the annual salary that he/she will receive if employed by Firm B.
Firm B has offered different annual salary amounts to different Firm A employees.
Firm B has offered to pay you the following annual salary: $
Compensation at Firm B will consist of this monetary incentive alone.
Firm B employees will not receive any non-monetary incentives.

Distribution of Salary Offers from Firm B
You do not know the salary amounts that Firm B has offered to other current employees at Firm A.

You know only that all of Firm B's salary offers are spread evenly over some range.
In other words, these salary offers are spread evenly between some lower bound & some upper bound.
You do not know the actual lower and upper bounds of the range of salary offers.
However, you do know that the salary offered to you by Firm B lies somewhere within this range of offers.
Thus, it likely that some of Firm B's salary offers to potential employees are higher than your offer above.
It is also likely that some of Firm B's salary offers to potential employees are lower than your offer.

Determining Which Employees to Retain at Firm A
Firm A will determine which 50 employees to retain -- and how each retained employee will be compensated using a survey regarding requested compensation.
This compensation survey will now consist of two parts
(1) An NMI survey in which each employee identifies which NMIs he/she wants to receive if retained; and
(2) A salary survey in which each employee specifies the minimum annual salary that he/she would need to receive in order to remain with Firm A assuming that he/she would also receive the NMI(s) requested.
Firm A will calculate the total cost of each employee's compensation request as the sum of:
(1) The cost of any NMIs or combination of NMIs he/she requested in the NMI survey, plus
(2) The annual salary amount he/she requested in the salary survey.
The 50 employees who submit the 50 lowest-cost compensation requests will be retained by Firm A.
The 50 employees who submit the 50 highest-cost compensation requests will be laid off.
Each of the laid off employees will immediately begin working at Firm B at the salary previously offered.

Determining Compensation for Employees at Firm A
Note that the 50 employees retained by Firm A will likely receive different compensation packages, because they will have presumably requested different NMIs in the NMI survey.
Nonetheless, the compensation package (salary plus NMIs) received by each retained employee will have the same total cost to Firm A, regardless of the NMIs or salary requested.
In particular, each retained employee will receive a compensation package whose total cost is equal to the cost of the lowest-cost compensation request among the 50 laid-off employees.
In other words, each retained employee will receive a compensation package whose total cost is equal to the cost of the 50th highest-cost compensation request.
To illustrate, let us refer to the cost of this 50th highest-cost compensation request as the "cutoff cost."
Note that each of the 50 retained employees will have submitted a compensation request whose total cost was below this cutoff cost.
Recall that each retained employee will receive whichever NMI or NMIs he/she requested in the NMI survey.
The salary for each employee retained by Firm A will then be determined as follows:

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

Thus, each Firm A employee receives a salary equal to the cutoff cost minus the total cost of NMIs received.
Note that, while salaries may vary, the total compensation cost for all Firm A employees will be the same.
Also note that the salary received by each Firm A employee does not depend upon either:
(1) the actual salary amount he/she requested, nor
(2) his or her value for either or both of the NMIs.

NMI Survey at Firm A
Recall that the value (to you) and the cost (to Firm A) associated with the NMIs offered is as follows:

	Value	Cost
NMI 1	$	$
NMI 2	$	$
Both NMIs	$	$

Please now select which, if any, of the two NMIs you would like to receive if retained by Firm A.
In doing so, please recall that:
(1) If you are retained by Firm A, you will receive any NMI chosen,
(2) The total value of your compensation at Firm A increases by the value of each NMI (or combination) chosen,
(3) The cost of each NMI chosen will be added to your salary request when determining whether you will be retained by Firm A (i.e., whether your compensation request is among the 50 lowest-cost requests), and
(4) In exchange for each NMI chosen, the cost of that NMI will be subtracted from your salary if retained by Firm A.

Please choose by selecting the button(s) next to the NMI(s) offered.

NMI 1
NMI 2

The total value and cost associated with the NMI selections above is:

Total NMI value for you: $
Total NMI cost for Firm A: $

Salary Survey at Firm A
Firm A is further asking each of its 100 workers to specify the minimum annual salary that he/she would need to receive in order to remain with Firm A, given that he/she would also receive the NMI(s) requested if retained.
Recall that Firm B is offering you: $
Thus, knowing Firm B's offer & that you will receive the NMIs selected above (& the associated total NMI value) if you remain with Firm A, what annual salary do you request from Firm A in addition to the NMI(s) chosen?

Salary Request to Firm A:

Total Value and Cost of Your Compensation Request

Given your NMI and salary requests above, note that the total value and cost of your combined requests are:

Total value (to you) of your compensation request : $
Total cost (to Firm A) of your compensation request: $

You May Click Button Whenever You Are Satisfied With Your NMI and Salary Requests Above.

a. Retained by Firm A

Same as Uniform Independent "Retained by Firm A"

b. Not Retained by Firm A

Same as Uniform Independent "Not retained by Firm A"

B. DISCRIMINATORY

1. Cash Bid

Scenario Background
You are 1 of 100 employees currently working for Firm A.
Your only other potential employer is Firm B.
You have no particular preference for Firm A or for Firm B.
You can easily switch employers at no cost or inconvenience to you.
Your only goal is to maximize the total value of your annual compensation.

Downsizing at Firm A
Firm A will be downsizing, and 50 of its 100 employees be will be laid off immediately.
After these one-time layoffs, however, employees will have the same level of job security at Firm A as at Firm B.

Employment Offer from Firm B
Firm B has offered to employ the 50 employees who are laid off by Firm A.
If you are laid off from Firm A now, you will work at Firm B immediately.

Salary Offer from Firm B
Firm B has presented a confidential annual salary offer to each employee currently working for Firm A.
The offer presented to each employee represents the annual salary that he/she will receive if employed by Firm B.
Firm B has offered different annual salary amounts to different Firm A employees.
Firm B has offered to pay you the following annual salary: $

Distribution of Salary Offers from Firm B
You do not know the salary amounts that Firm B has offered to other current employees at Firm A.

You know only that all of Firm B's salary offers are spread evenly over some range.
In other words, these salary offers are spread evenly between some lower bound & some upper bound.
You do not know the actual lower and upper bounds of the range of salary offers.
However, you do know that the salary offered to you by Firm B lies somewhere within this range of offers.
Thus, it likely that some of Firm B's salary offers to potential employees are higher than your offer above.
It is also likely that some of Firm B's salary offers to potential employees are lower than your offer.

Salary Survey at Firm A
The salary paid to any Firm A employee in previous years will have no influence on his/her future salary at Firm A.
Instead, the annual salary that Firm A will pay to each of its retained employees will be determined using a survey.
The survey asks each Firm A employee to indicate the annual salary amount he/she requires to remain with Firm A.
Firm A will then retain the 50 of its 100 employees who submitted the 50 lowest salary requests.
In other words, after collecting all 100 salary requests from its employees, Firm A will lay off the 50 employees who submitted the 50 highest salary requests.
Each of the 50 employees laid off will immediately begin working at Firm B at the salary previously offered.
The remaining 50 employees will work at Firm A (they do not have the option at that point to work for Firm B).
Each employee retained by Firm A will be paid whatever annual salary amount he/she requested in the salary survey.
Thus, different Firm A employees will receive different annual salaries, matching their salary survey responses.

Your Salary Request to Firm A
You must now decide what annual salary to request from Firm A.
Remember that if your request is among the 50 highest salary requests submitted, you will be laid off from Firm A and will work for Firm B.
If your salary request to Firm A is among the 50 lowest requests, you will continue to work for Firm A and will receive whatever annual salary you requested in the salary survey.

Recall that Firm B is offering you: $

What annual salary do you request from Firm A:

Salary Request to Firm A:

You May Click Button Whenever You Are Satisfied With Your Salary Request Above.

a. Retained by Firm A

Results
Your salary request was among the 50 lowest requested, and you will therefore be retained by Firm A.

Distribution of Salary Requests to Firm A
The lowest annual salary request submitted to Firm A by one of its current employees was: $
The highest annual salary request submitted to Firm A by one of its current employees was: $
The 50th highest annual salary request submitted to Firm A by one of its current employees was: $
Your annual salary request to Firm A was: $

Your Employer and Salary
Since your salary request was among the 50 lowest requests submitted to Firm A, you will be retained by Firm A.
Your salary will be equal to the annual salary amount you requested in the salary survey.
Thus, your salary will be: $

The salary above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

b. Not Retained by Firm A

Results
Your salary request was among the 50 highest requested, and you will therefore not be retained by Firm A.
You will now be employed by Firm B.

Distribution of Salary Requests to Firm A
The lowest annual salary request submitted to Firm A by one of its other current employees was: $
The highest annual salary request submitted to Firm A by one of its other current employees was: $
The 50th highest annual salary request submitted to Firm A by one of its current employees was: $
Your annual salary request to Firm A was: $

Your Employer and Salary
Since your salary request was among the 50 highest requests submitted to Firm A.
You will not be retained by Firm A and will instead be employed by Firm B.
Your salary will be equal to the offer provided by Firm B.
Thus, your salary will be: $

The salary above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

2. Independent NMI Bid

Scenario Background
You are 1 of 100 employees currently working for Firm A.
Your only other potential employer is Firm B.
You have no particular preference for Firm A or for Firm B.
You can easily switch employers at no cost or inconvenience to you.
Your only goal is to maximize the total value of your annual compensation.
Your compensation may now include both monetary and non-monetary incentives.

Non-Monetary Incentives (NMIs)
A non-monetary incentive (NMI) is any benefit provided to an employee other than cash compensation.
Examples of NMIs include such benefits as:
-- Housing or education assistance,
-- Flexible work arrangements, and
-- Choice of a particular office, location, or position
Firm A is offering two potential non-monetary incentives which will be generically labeled NMI 1 and NMI 2.
In addition to his/her salary, each employee retained by Firm A will receive either:
(a) NMI 1 only.
(b) NMI 2 only.
(c) Both NMI 1 and NMI 2, or
(d) Neither NMI 1 nor NMI 2.
In fact, each employee retained by Firm A will choose which NMI or NMIs he/she would like to receive.
How these choices are made will be described in more detail below.

Your Value for Non-Monetary Incentives
Your values for each of the two NMIs offered by Firm A (and for both NMIs in combination) are as follows:

	Value
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

These amounts reflect your cash equivalent value for each NMI as well as the combination of both NMIs.
In other words, each NMI has the same value to you as the corresponding cash amount indicated above.
Put another way, you would rather receive the NMI than any cash amount less than the value indicated.
Conversely, you would rather receive any cash amount greater than the indicated value than receive the NMI.
Also, note that your value for both NMIs together is simply the sum of the two individual NMI values.
With the possibility of receiving NMIs, the total value of your annual compensation will now be the sum of:
(1) Your annual salary amount, plus
(2) Your value for any NMIs or combination of NMIs you receive
Recall that your actual cash earnings from this experiment are determined by this total value of your annual compensation, not by your salary alone.
Please also note that your NMI values will change in each round of the experiment.

The Distribution of NMI Values

Different employees value each NMI differently.
Some employees will value an NMI very highly while others will assign very little value to the very same NMI.
For each of the two NMIs offered by Firm A, employee valuations range between $0 and $25,000.
Moreover, the employee values for each NMI are spread evenly over this range.
Thus, you know that any other employee could value a particular NMI as little as $0 or as much as $25,000, with each value between those extremes being equally likely.

The Cost of Non-Monetary Incentives
Firm A must incur some cost to provide either NMI (or both NMIs) to one of its employees.
Firm A's cost of providing each of the two NMIs (or both NMIs in combination) is as follows:

	Cost
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

Note that Firm A's cost to provide both NMIs together is simply the sum of the two individual NMI costs.

Downsizing at Firm A
Firm A will be downsizing, and 50 of its 100 employees be will be laid off immediately.
After these one-time layoffs, however, employees will have the same level of job security at Firm A as at Firm B.

Employment Offer from Firm B
Firm B has offered to employ anybody who leaves Firm A.
If you leave Firm A now, you will work at Firm B immediately.
This standing offer of employment at Firm B applies whether you leave Firm A voluntarily or are laid off.

Salary Offer from Firm B
Firm B has presented a confidential annual salary offer to each employee currently working for Firm A.
The offer presented to each employee represents the annual salary that he/she will receive if employed by Firm B.
Firm B has offered different annual salary amounts to different Firm A employees.
Firm B has offered to pay you the following annual salary: $
Compensation at Firm B will consist of this monetary incentive alone.
Firm B employees will not receive any non-monetary incentives.

Distribution of Salary Offers from Firm B
You do not know the salary amounts that Firm B has offered to other current employees at Firm A.
You know only that all of Firm B's salary offers are spread evenly over some range.
In other words, these salary offers are spread evenly between some lower bound & some upper bound.
You do not know the actual lower and upper bounds of the range of salary offers.
However, you do know that the salary offered to you by Firm B lies somewhere within this range of offers.
Thus, it likely that some of Firm B's salary offers to potential employees are higher than your offer above.
It is also likely that some of Firm B's salary offers to potential employees are lower than your offer.

Determining Which Employees to Retain at Firm A
Firm A will determine which 50 employees to retain -- and how each retained employee will be compensated using a survey regarding requested compensation.
This compensation survey will now consist of two parts
(1) An NMI survey in which each employee identifies which NMIs he/she wants to receive if retained; and
(2) A salary survey in which each employee specifies the minimum annual salary that he/she would need to receive in order to remain with Firm A assuming that he/she would also receive the NMI(s) requested.
Firm A will calculate the total cost of each employee's compensation request as the sum of:
(1) The cost of any NMIs or combination of NMIs he/she requested in the NMI survey, plus
(2) The annual salary amount he/she requested in the salary survey.
The 50 employees who submit the 50 lowest-cost compensation requests will be retained by Firm A.
The 50 employees who submit the 50 highest-cost compensation requests will be laid off.
Each of the laid off employees will immediately begin working at Firm B at the salary previously offered.

Determining Compensation for Employees at Firm A

Note that the 50 employees retained by Firm A will likely receive different compensation packages, because they will have presumably requested different NMIs in the NMI survey and different salaries in the salary survey.
Each employee retained by Firm A will receive whichever NMI or NMIs he she requested, his/her value for these NMIs will be added to the total value of his/her overall compensation.
Each employee retained by Firm A will also receive whatever salary amount he/she requested.
Thus, if you are retained by Firm A, the total value of your annual compensation will be the sum of:
(1) Whatever annual salary amount your requested in the salary survey, plus
(2) Your value for any NMIs or combination of NMIs you requested in the NMI survey.

NMI Survey at Firm A
Recall that the value (to you) and the cost (to Firm A) associated with the NMIs offered is as follows:

	Value	Cost
NMI 1	$	$
NMI 2	$	$
Both NMIs	$	$

Please now select which, if any, of the two NMIs you would like to receive if retained by Firm A.
In doing so, please recall that:
(1) If you are retained by Firm A, you will receive any NMI chosen,
(2) The total value of your compensation at Firm A increases by the value of each NMI (or combination) chosen,
(3) The cost of each NMI chosen will be added to your salary request when determining whether you will be retained by Firm A (i.e., whether your compensation request is among the 50 lowest-cost requests), and
(4) In exchange for each NMI chosen, the cost of that NMI will be subtracted from your salary if retained by Firm A.
Please choose by selecting the button(s) next to the NMI(s) offered.

NMI 1
NMI 2

The total value and cost associated with the NMI selections above is:

Total NMI value for you: $
Total NMI cost for Firm A: $

Salary Survey at Firm A
Firm A is further asking each of its 100 workers to specify the minimum annual salary that he/she would need to receive in order to remain with Firm A, given that he/she would also receive the NMI(s) requested if retained.
Recall that Firm B is offering you: $
Thus, knowing Firm B's offer & that you will receive the NMIs selected above (& the associated total NMI value) if you remain with Firm A, what annual salary do you request from Firm A in addition to the NMI(s) chosen?

Salary Request to Firm A:

Total Value and Cost of Your Compensation Request

Given your NMI and salary requests above, note that the total value and cost of your combined requests are:

Total value (to you) of your compensation request : $
Total cost (to Firm A) of your compensation request: $

You May Click Button Whenever You Are Satisfied With Your NMI and Salary Requests Above.

a. Retained by Firm A

Results
The total cost of your compensation request was among the 50 lowest-cost requests submitted to Firm A.
In other words, the total cost of your compensation request was below the "cutoff cost" among all requests.
Therefore, you will be retained by Firm A.

Distribution of Salary Requests to Firm A
The lowest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The highest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The 50th highest ("cutoff") cost of all compensation requests submitted to Firm A by one of its employees was: $
The total cost of the compensation request you submitted to Firm A was: $

Your Non-Monetary Incentives
Recall that the value (to you) and the cost (to Firm A) associated with the NMIs offered was as follows:

	Value	Cost
NMI 1	$	$
NMI 2	$	$
Both NMIs	$	$

Because you are to be retained by Firm A, you will receive any NMIs you requested in the compensation survey.

Thus, the NMIs included as part of your compensation at Firm A will be as follows:

	Received?
NMI 1	YES/NO
NMI 2	YES/NO

The total value and cost associated with the NMIs you will receive are as follows:

Total NMI value for you: $
Total NMI cost for Firm A: $

Your Salary

Recall that each employee retained by Firm A receives whatever salary he/she requested in the salary survey.
Thus, your annual salary will be: $

Total Value of Your Annual Compensation
The total value of your annual compensation is therefore given by:

Annual salary: $
Total NMI value: $
Total compensation value: $

The total compensation value above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

b. Not Retained by Firm A

Results
The total cost of your compensation request was among the 50 highest-cost requests submitted to Firm A.
In other words, the total cost of your compensation request was above the "cutoff cost" among all requests.
Therefore, you will not be retained by Firm A and will now be employed by Firm B.

Distribution of Salary Requests to Firm A
The lowest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The highest cost of all compensation requests submitted to Firm A by one of its other current employees was: $
The 50th highest ("cutoff") cost of all compensation requests submitted to Firm A by one of its employees was: $
The total cost of the compensation request you submitted to Firm A was: $

Your Salary
As indicated, you will not be retained by Firm A and will instead be employed by Firm B.
Because Firm B does not offer NMIs, the total value of your compensation will be reflected in your annual salary.
Your salary will be equal to the amount previously offered to you by Firm B.
Thus, your salary will be: $

The salary above is your experimental earnings for this round.
This total of all the rounds will be converted to actual earnings from participation in this experiment at the exchange rate of $150,000 of experimental income = $1 of actual earnings.

Please wait until instructed to do so before clicking on the button below.

Please Do Not Click Button Until Instructed to Do So. Thank You.

3. Combinatorial NMI Bid

Scenario Background
You are 1 of 100 employees currently working for Firm A.
Your only other potential employer is Firm B.
You have no particular preference for Firm A or for Firm B.

You can easily switch employers at no cost or inconvenience to you.
Your only goal is to maximize the total value of your annual compensation.
Your compensation may now include both monetary and non-monetary incentives.

Non-Monetary Incentives (NMIs)
A non-monetary incentive (NMI) is any benefit provided to an employee other than cash compensation.
Examples of NMIs include such benefits as:
-- Housing or education assistance,
-- Flexible work arrangements, and
-- Choice of a particular office, location, or position
Firm A is offering two potential non-monetary incentives which will be generically labeled NMI 1 and NMI 2.
In addition to his/her salary, each employee retained by Firm A will receive either:
(a) NMI 1 only.
(b) NMI 2 only.
(c) Both NMI 1 and NMI 2, or
(d) Neither NMI 1 nor NMI 2.
In fact, each employee retained by Firm A will choose which NMI or NMIs he/she would like to receive.
How these choices are made will be described in more detail below.

Your Value for Non-Monetary Incentives
Your values for each of the two NMIs offered by Firm A (and for both NMIs in combination) are as follows:

	Value
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

These amounts reflect your cash equivalent value for each NMI as well as the combination of both NMIs.
In other words, each NMI has the same value to you as the corresponding cash amount indicated above.
Put another way, you would rather receive the NMI than any cash amount less than the value indicated.
Conversely, you would rather receive any cash amount greater than the indicated value than receive the NMI.
Also, note that your value for both NMIs together is simply the sum of the two individual NMI values.
With the possibility of receiving NMIs, the total value of your annual compensation will now be the sum of:
(1) Your annual salary amount, plus
(2) Your value for any NMIs or combination of NMIs you receive.
Recall that your actual cash earnings from this experiment are determined by this total value of your annual compensation, not by your salary alone.
Please also note that your NMI values will change in each round of the experiment.

The Value of NMIs in Combination
The value to you from receiving both NMIs will now often not be equal to the sum of the two individual NMI values.
Sometimes, the value of the combination may be greater than the sum of the two individual NMI values.
At other times, the value of the combination may be less than the sum of the two individual NMI values.
In either case, the value of the combination may influence which NMI or NMIs (if any) you want to choose.

The Distribution of NMI Values
Different employees value each NMI differently.
Some employees will value an NMI very highly while others will assign very little value to the very same NMI.
For each of the two NMIs offered by Firm A, employee valuations range between $0 and $25,000.
Moreover, the employee values for each NMI are spread evenly over this range.
Thus, you know that any other employee could value a particular NMI as little as $0 or as much as $25,000, with each value between those extremes being equally likely.

The Cost of Non-Monetary Incentives
Firm A must incur some cost to provide either NMI (or both NMIs) to one of its employees.
Firm A's cost of providing each of the two NMIs (or both NMIs in combination) is as follows:

	Cost
NMI 1 only	$
NMI 2 only	$
Both NMI 1 and NMI 2	$

Note that Firm A's cost to provide both NMIs together is simply the sum of the two individual NMI costs.

Downsizing at Firm A
Firm A will be downsizing, and 50 of its 100 employees be will be laid off immediately.
After these one-time layoffs, however, employees will have the same level of job security at Firm A as at Firm B.

Employment Offer from Firm B
Firm B has offered to employ anybody who leaves Firm A.
If you leave Firm A now, you will work at Firm B immediately.
This standing offer of employment at Firm B applies whether you leave Firm A voluntarily or are laid off.

Salary Offer from Firm B
Firm B has presented a confidential annual salary offer to each employee currently working for Firm A.
The offer presented to each employee represents the annual salary that he/she will receive if employed by Firm B.
Firm B has offered different annual salary amounts to different Firm A employees.
Firm B has offered to pay you the following annual salary: $
Compensation at Firm B will consist of this monetary incentive alone.
Firm B employees will not receive any non-monetary incentives.

Distribution of Salary Offers from Firm B
You do not know the salary amounts that Firm B has offered to other current employees at Firm A.
You know only that all of Firm B's salary offers are spread evenly over some range.
In other words, these salary offers are spread evenly between some lower bound & some upper bound.
You do not know the actual lower and upper bounds of the range of salary offers.
However, you do know that the salary offered to you by Firm B lies somewhere within this range of offers.
Thus, it likely that some of Firm B's salary offers to potential employees are higher than your offer above.
It is also likely that some of Firm B's salary offers to potential employees are lower than your offer.

Determining Which Employees to Retain at Firm A
Firm A will determine which 50 employees to retain -- and how each retained employee will be compensated using a survey regarding requested compensation.
This compensation survey will now consist of two parts
(1) An NMI survey in which each employee identifies which NMIs he/she wants to receive if retained; and
(2) A salary survey in which each employee specifies the minimum annual salary that he/she would need to receive in order to remain with Firm A assuming that he/she would also receive the NMI(s) requested.
Firm A will calculate the total cost of each employee's compensation request as the sum of:
(1) The cost of any NMIs or combination of NMIs he/she requested in the NMI survey, plus
(2) The annual salary amount he/she requested in the salary survey.
The 50 employees who submit the 50 lowest-cost compensation requests will be retained by Firm A.
The 50 employees who submit the 50 highest-cost compensation requests will be laid off.
Each of the laid off employees will immediately begin working at Firm B at the salary previously offered.

Determining Compensation for Employees at Firm A

Note that the 50 employees retained by Firm A will likely receive different compensation packages, because they will have presumably requested different NMIs in the NMI survey and different salaries in the salary survey.
Each employee retained by Firm A will receive whichever NMI or NMIs he she requested, his/her value for these NMIs will be added to the total value of his/her overall compensation.
Each employee retained by Firm A will also receive whatever salary amount he/she requested.
Thus, if you are retained by Firm A, the total value of your annual compensation will be the sum of:
(1) Whatever annual salary amount your requested in the salary survey, plus
(2) Your value for any NMIs or combination of NMIs you requested in the NMI survey.

NMI Survey at Firm A
Recall that the value (to you) and the cost (to Firm A) associated with the NMIs offered is as follows:

	Value	Cost
NMI 1	$	$
NMI 2	$	$
Both NMIs	$	$

Please now select which, if any, of the two NMIs you would like to receive if retained by Firm A.
In doing so, please recall that:
(1) If you are retained by Firm A, you will receive any NMI chosen,
(2) The total value of your compensation at Firm A increases by the value of each NMI (or combination) chosen,
(3) The cost of each NMI chosen will be added to your salary request when determining whether you will be retained by Firm A (i.e., whether your compensation request is among the 50 lowest-cost requests), and
(4) In exchange for each NMI chosen, the cost of that NMI will be subtracted from your salary if retained by Firm A.

Please choose by selecting the button(s) next to the NMI(s) offered.

NMI 1
NMI 2

The total value and cost associated with the NMI selections above is:

Total NMI value for you: $
Total NMI cost for Firm A: $

Salary Survey at Firm A
Firm A is further asking each of its 100 workers to specify the minimum annual salary that he/she would need to receive in order to remain with Firm A, given that he/she would also receive the NMI(s) requested if retained.
Recall that Firm B is offering you: $
Thus, knowing Firm B's offer & that you will receive the NMIs selected above (& the associated total NMI value) if you remain with Firm A, what annual salary do you request from Firm A in addition to the NMI(s) chosen?

Salary Request to Firm A:

Total Value and Cost of Your Compensation Request

Given your NMI and salary requests above, note that the total value and cost of your combined requests are:

Total value (to you) of your compensation request : $
Total cost (to Firm A) of your compensation request: $

You May Click Button Whenever You Are Satisfied With Your NMI and Salary Requests Above.

a. Retained by Firm A

Same as Discriminatory Independent "Retained by Firm A"

b. Not Retained by Firm A

Same as Discriminatory Independent "Not retained by Firm A"

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APPENDIX E. EXPERIMENT NOTES

Experiment After-Action Notes:

4 February 2010, 1300
Experimenters – Peter Coughlan, Noah Myung, Kyle Hahn, Marlow Levy

- Started on time.
- Used 17 of 18 computers in computer lab (In-224), computer #15 was not working.
- Uniform (second-price) auction session.
- Depicted cutoff costs on results page did not include NMIs cost. Corrected after experiment. Analysis will determine if it affected results.

5 February 2010, 1200
Experimenters - Peter Coughlan, Kyle Hahn, Marlow Levy

- Started on time.
- Used 17 of 18 computers in computer lab (In-224), computer #15 was not working.
- Discriminatory (first-price) auction session.
- Practice Survey A had a random green highlighted line.
- Interdependent NMIs (rounds 11-20), Salary Request Cost was not calculating correctly. Had volunteers leave the room for 10 minutes to correct the problem.
- Upon correcting the Salary Request Cost calculation, ghost images with numbers started to appear on the screen. Unprotected the workbooks to try and make images go away, it did not work. Other than being an inconvenience, it is unknown if the random ghost images gave volunteers an advantage or not. Experimenters watched volunteers to see if anyone was trying to incorporate ghost images in their calculation or use the visible tabs to their advantage, no volunteer appeared to be.
- Last five monetary (rounds 26-30), were supposed to be set up for discriminatory but were calculating for uniform.
- Volunteer (#7) had to leave at 1330.
- Volunteer (#14) had to leave at 1345 for family issues and came back to finish the experiment within five minutes.

5 February 2010, 1500

Experimenters - Peter Coughlan, Kyle Hahn, Marlow Levy

- Started on time.
- Used 17 of 18 computers in computer lab (In-224), computer #15 was not working.
- Discriminatory (first-price) auction session.
- Last five monetary (rounds 26-30), were incorrectly linked and did not show winning bid, only if you were retained or not. However, the data was still recorded correctly and would have not affected results.
- Volunteer (#9) closed the computer without saving, losing all the data.

APPENDIX F. SUPPORTING DATA

		Actual Bid Value	Actual Bid Value	Actual Bid Value	Actual Bid Value	Actual Bid Cost Request vs.	
		Uniform		Discriminatory		Uniform	Discrim
All Rounds	Mean	104.7%	104.5%	98.6%	99.6%	104.7%	100.0%
	σ	21.4%	20.0%	17.3%	17.1%	18.5%	15.8%
	Median	101.9%	100.9%	98.0%	98.3%	102.2%	98.8%
Monetary	Mean	103.9%	103.9%	100.1%	100.1%	103.9%	100.1%
	σ	20.0%	20.0%	17.3%	17.3%	20.0%	17.3%
	Median	100.0%	100.0%	97.9%	97.9%	100.0%	97.9%
NMI Additive	Mean	106.1%	106.7%	98.5%	100.1%	106.3%	100.5%
	σ	22.9%	22.0%	18.8%	19.0%	19.0%	16.7%
	Median	105.0%	103.0%	98.4%	98.4%	104.0%	99.0%
NMI Combinatorial	Mean	104.0%	103.0%	97.1%	98.6%	104.0%	99.4%
	σ	21.1%	17.6%	15.6%	14.8%	16.2%	13.2%
	Median	101.9%	100.7%	97.4%	99.3%	102.5%	99.6%
Monetary (1-5)	Mean	105.5%	105.5%	101.9%	101.9%	105.5%	101.9%
	σ	22.7%	22.7%	19.9%	19.9%	22.7%	19.9%
Additive (6-10)	Mean	111.6%	111.3%	98.8%	100.9%	110.6%	101.2%
	σ	20.7%	21.3%	19.3%	20.5%	17.3%	17.9%
Combin (11-15)	Mean	101.1%	101.3%	94.6%	97.4%	102.5%	98.3%
	σ	21.7%	19.0%	15.0%	14.5%	18.1%	12.8%
Combin (16-20)	Mean	106.8%	104.7%	99.6%	99.8%	105.4%	100.4%
	σ	20.2%	16.0%	15.9%	15.1%	14.0%	13.5%
Additive (21-25)	Mean	100.7%	102.0%	98.1%	99.3%	102.1%	99.8%
	σ	23.8%	21.9%	18.4%	17.4%	19.8%	15.4%
Monetary (26-30)	Mean	102.3%	102.3%	98.4%	98.4%	102.3%	98.4%
	σ	16.9%	16.9%	14.1%	14.1%	16.9%	14.1%
Complex Choice	Mean	103.4%	102.3%	97.0%	97.7%	103.2%	98.3%
	σ	25.9%	21.7%	11.3%	10.9%	21.1%	9.9%
Experience	Mean	101.0%	100.1%	96.5%	97.9%	101.8%	98.4%
	σ	13.0%	1.6%	16.2%	15.9%	2.9%	14.7%

		Actual vs Optimal Outcomes			
		Value	Cost	Value	Cost
		Uniform		Discriminatory	
All Rounds	Mean	98.6%	99.0%	94.8%	95.1%
	σ	4.3%	4.3%	8.9%	8.6%
	Median	100.0%	100.0%	100.0%	100.0%
Monetary	Mean	98.8%	98.8%	94.4%	94.4%
	σ	4.4%	4.4%	8.9%	8.9%
	Median	100.0%	100.0%	100.0%	100.0%
NMI Additive	Mean	98.4%	99.0%	95.0%	95.3%
	σ	4.6%	4.4%	8.8%	8.5%
	Median	100.0%	100.0%	100.0%	100.0%
NMI Combinatorial	Mean	98.5%	99.2%	95.0%	95.5%
	σ	4.0%	4.0%	9.0%	8.4%
	Median	100.0%	100.0%	100.0%	100.0%
Monetary (1-5)	Mean	98.7%	98.7%	94.3%	94.3%
	σ	4.8%	4.8%	9.0%	9.0%
Additive (6-10)	Mean	98.0%	98.6%	95.0%	95.2%
	σ	5.0%	4.7%	8.9%	8.7%
Combin (11-15)	Mean	98.8%	99.5%	94.5%	95.1%
	σ	3.6%	3.7%	9.7%	9.3%
Combin (16-20)	Mean	98.2%	98.8%	95.5%	95.9%
	σ	4.3%	4.3%	8.2%	7.4%
Additive (21-25)	Mean	98.8%	99.5%	95.0%	95.3%
	σ	4.2%	4.0%	8.7%	8.4%
Monetary (26-30)	Mean	99.0%	99.0%	94.6%	94.6%
	σ	4.1%	4.1%	8.8%	8.8%
Complex Choice	Mean	97.8%	98.3%	96.4%	96.6%
	σ	5.5%	5.3%	7.4%	7.1%
Experience	Mean	99.4%	100.1%	94.7%	94.9%
	σ	1.8%	0.6%	8.9%	8.6%

Percent Errors	Uniform				Discriminatory			
	Type 1	Type 2	Invol Ret.	Unrealized Value	Type 1	Type 2	Invol Ret.	Unrealized Value
All Rounds	3%	8%	4%	10%	7%	8%	4%	21%
Monetary	4%	7%	4%	9%	8%	9%	3%	22%
NMI Additive	2%	12%	2%	14%	8%	8%	2%	23%
NMI Combinatorial	5%	6%	5%	11%	5%	6%	6%	20%
Monetary (1-5)	5%	8%	5%	9%	10%	13%	3%	23%
Additive (6-10)	2%	14%	2%	6%	9%	8%	3%	27%
Combin (11-15)	4%	6%	5%	11%	4%	4%	8%	23%
Combin (16-20)	6%	6%	6%	10%	7%	8%	4%	15%
Additive (21-25)	1%	11%	0%	29%	7%	9%	1%	15%
Monetary (26-30)	2%	6%	2%	8%	6%	6%	2%	21%
Complex Choice	7%	9%	9%	10%	7%	5%	4%	10%
Experience	0%	3%	0%	0%	6%	6%	3%	21%

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