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An Experimental Analysis of the Relative Efficiency of Alternative Assignment Auction Formats

R. Wesley Nimon, Ph.D.
Ricky D. Hall, M.A.

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14. ABSTRACT
To induce Sailors to volunteer for hard-to-fill assignments the Navy employs an auction. With respect to the optimal assignment auction format; however, there is only very limited academic literature. To match Sailors with qualified bidders, non-bid factors must be reflected in the assignment. The greater the weight placed on those factors, the lower the weight placed on the bid and hence the weaker the Sailor's incentive to bid near his reservation wage. This requirement precludes the implementation of an incentive compatible assignment auction (Leonard, 1983). This report relaxes the assumption that the bid amounts alone determine the assignment set and experimentally estimates the efficiency reductions associated with decreased bid weights. The estimated elasticity of payment to changes in the bid weight in a low-contention, first-price auction, with a bid weight of 10% is -0.34. The effect of the contention level (i.e., the ratio of bidders to jobs) is identified as well. A third consideration is whether a first or a Modified Vickrey-Leonard (VL) auction offers smaller efficiency reductions when the assumption of 100% bid weight is relaxed.

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Foreword

This report was prepared to summarize analysis done under the Distribution Incentive System (DIS), a 6.3 research project funded by the Office of Naval Research (ONR) under the FNC ACQUIRE. Specifically, it details the development of an empirical approach to identify the tradeoffs associated with alternative assignment auction specifications, describes the experiments conducted, presents the subsequent data analysis, and draws auction design recommendations.

The authors wish to thank our project manager, LCDR Mike Jones, Professor James Smith at Southern Methodist University, Associate Professor Bill Gates at Naval Postgraduate School (NPS), Assistant Professor Pete Coughlan at NPS, Assistant Professor Glen Archibald at the University of Mississippi, and University of Memphis faculty member Chris Dula for the helpful comments and assistance.

DAVID L. ALDERTON, Ph.D.
Director

Executive Summary

For many years recruits have entered the Navy as volunteers. Once in the Navy, though, an individual assignment that a Sailor receives is the result of negotiations between him and his detailer (assignment coordinator) and does not always reflect the desires of the Sailor. In July of 2003 the Navy began an initiative to rectify the hard-to-fill situation. Assignment Incentive Pay (AIP) was authorized by Congress to be paid as a monthly stipend to attract Sailors to volunteer for hard-to-fill assignments. An auction was determined to be the best method for distributing the AIP stipends. With respect to the optimal assignment auction format, however, there is only very limited academic literature. Furthermore, the literature that does exist assumes that all bidders are equally qualified and that there is a 100 percent weight placed on the bid in the objective function of the optimization routine. In the Navy assignment context this is not a tenable assumption as other considerations, such as Permanent Change of Station (PCS) cost and required training, must be considered when making an assignment. The lower the weight on the bid, the greater the weight that can be attached to the qualification component of the assignment determination. The lower the weight, however, the weaker the incentive to bid one's reservation wage (RW). This qualification requirement precludes the implementation of the incentive compatible assignment auction described in Leonard (1983). This paper relaxes the assumption that the bid amounts alone determine the assignment set and experimentally estimates the efficiency reductions associated with decreased bid-weights. The effect of the contention level (i.e., the ratio of bidders to jobs) is identified as well. A third consideration is whether a first or a Modified Vickrey-Leonard (VL) auction offers smaller efficiency reductions when the assumption of 100 percent bid-weight is relaxed. These selected auction designs are empirically analyzed using data generated from the developed experimental framework.

It was hypothesized that a variant of the second-price auction, a Modified Vickery-Leonard auction, might lower bids sufficiently enough to make that the least-cost approach for the Navy. While the bids submitted were generally lower, the payments were significantly higher. While a larger pool of bidders would mitigate this outcome, more than six bidders for a Navy billet cannot be guaranteed. As such, the recommendation is to pursue a first-price auction approach.

Significant premiums above the Sailor's reservation wage are likely without a substantial weight being placed on the bid. As expected, the amount paid to the bidder varies inversely with bid-weight. Attaching a low weight to the bids, especially one less than 50 percent, results in substantially inflated bids and payments to the bidders. The estimated elasticity of payment to changes in the bid-weight in a low-contention, first-price auction with a 10 percent bid weight is –0.35. This implies that a 1 percent increase in the bid-weight lowers the average winning bid amount by 0.35 percent. Increasing the bid-weight from 10 percent to 50 percent decreases the expected winning bid by approximately 28 percent. With a high-contention environment the bid-weight elasticity is estimated to be slightly less inelastic.

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Introduction

Background

Despite incremental improvements over time, the current system used to match Sailors with jobs still relies on a system with limited flexibility to create compensating wage differentials for difficult assignments and encourage the retention of Sailors with significant private sector opportunity costs. The current system relies heavily on a rigid pay structure that is largely determined by rank and years of service. Being far removed from the era of the draft and facing a robust private sector labor demand, the U.S. Navy (hereafter Navy) faces an increasingly difficult challenge recruiting and retaining highly skilled Sailors. Although current incentives allow some flexibility for location-specific re-enlistment bonuses, the fact that some jobs are repeatedly filled by forced assignments of Sailors to them, suggests that the current set of incentives lack the flexibility necessary to elicit volunteers for all Navy job assignments. To determine the least amount of money the Navy must pay to assign a qualified enlisted Sailor to hard-to-fill jobs, the Navy has implemented a rudimentary auction-like format for a small number of job assignments (Jaffe, 2003). To empirically test alternative auction parameterizations, we developed an empirical approach to identify the tradeoffs associated with alternative specifications, and conducted the necessary experiments.

Literature

For cases in which private values are known, assignment algorithms such as the stable marriage-matching algorithm (Gale & Shapley, 1969) are well developed. Leonard (1983) proposed an assignment auction mechanism intended to elicit private valuations to optimally assign individuals to slots. This mechanism has a dominant strategy equilibrium in which each agent reveals his true valuation, which allows an outcome-efficient assignment. The extent to which consumer surplus is extracted from the agents depends on the preference profiles of the bidders. Olson and Porter (1994) empirically compare the Vickery-Leonard assignment auction to other mechanisms. We relax the assumption that each bidder is equally qualified and that 100 percent weight is placed on the bid. By doing so, the dominant strategy deviates from truthful revelation. In an experimental setting, we investigate the extent to which bidding strategies likely deviate from truthful revelation as the bid-weight diminishes.

Statement of the Problem

Assignment auctions are unique from other auction types in that each bidder can only be assigned one job and that one's bid on any given job affects not just the probability of assignment to that job but, indirectly, the probability of assignment to any other job.

Further complicating the Navy's assignment problem, other factors such as how early or late will the Sailor arrive and the additional training (if any) he will require, must be considered along with the Sailor's bid in the assignment determination process. The lower the weight on the bid, the greater the weight that can be attached to these other desirable criteria when determining job assignments. The lower the weight placed on the Sailor's bid, however, the weaker the incentive to bid his reservation wage (RW). The consideration of these other factors precludes

the implementation of the incentive compatible assignment auction described in Leonard (1983). We relax the assumption that the bid amounts alone determine the assignment set and experimentally estimate the efficiency reductions associated with decreased bid-weights. The effect of contention levels (the ratio of bidders to jobs) is identified as well. A third consideration is whether a first-price, sealed-bid or a Modified Vickrey-Leonard (VL) auction (i.e., a VL auction in which the bid-weight is less then 1) offers smaller efficiency reductions when the assumption of a 100 percent bid-weight is relaxed.

While the motivation for this research lays in its military application, many large firms and some government agencies regularly rotate their mid-level management personnel so that they have a broad perspective on the organization's operations. For example, the U.S. Department of Agriculture's Foreign Agriculture Service periodically rotates its staff from embassy to embassy. Some posts are more desirable than others, and some personnel are more qualified than others, and so achieving stable, optimal matches by identifying uncertain compensating wage differentials may be best achieved with a job assignment auction. This report focuses on the case in which the organization must reflect both each individual's bid and qualifications when assigning a group of individuals to a group of jobs. This paper empirically identifies the sensitivity of the level of the bids to the weight placed on the bid. In other words, how expensive is it to achieve quality matches?

Model

Assignment Determination

In this approach each bidder will have a total score for each job that is a weighted function of both his bid and a randomly selected fitness score. This allows an assignment auction to reflect quality into the assignment decisions and the agent's bid.

Let $z_{ij} = 100\alpha\left(1 - b_{ij} / s_{max}\right) + \left(1 - \alpha\right) f_{ij}$

The bids submitted for the jobs are denoted by b_{ij}, which is the bid of bidder i for job j. The fitness score for bidder i for job j is denoted by f_{ij}. The fitness score represents the bidders qualification for the job over which he has no control. The weight placed on the fitness score is $(1 - \alpha)$ and the maximum allowable bid is denoted by s_{max}, which is defined as 100 in the experiment. Thus, $z_{ij} = \alpha\left(100 - b_{ij}\right) + \left(1 - \alpha\right) f_{ij}$.

In keeping with Leonard (1983), the assignments selected are those that maximize the sum of the total scores across the J available jobs.

$$\text{Max: } Z = \sum_{i=1}^{6} \sum_{j=1}^{J} z_{ij} x_{ij} \ ,$$

$$\text{s.t.} \sum_{j=1}^{J} x_{ij} \le 1 \text{ for any i, (each person can be assigned at most one job) and}$$

$$\sum_{i=1}^{6} x_{ij} = 1 \text{ for any j (exactly one person assigned to each job).}$$

where x_{ij} = 1 if subject i is assigned to job j and 0 otherwise. The solution set is constrained such that no bidder will be awarded more than one job and each job must be assigned to exactly one bidder. This differs from Leonard in that the objective function being maximized is a weighted sum of both the bid score and the fitness score.

Experimental Design

Our experimental design consisted of three fixed factors: type of mechanism (modified VL auction and first-price auction), contention level (high and low), and weight on the bid (80%, 66%, 50%, 34%, 20%, and 10%). As in Olson and Porter (1994), we considered an environment in which there are six agents. To consider both high and low levels of contention, the ratio of jobs to bidders varied from 3/6 to 5/6, respectively.

There were six bidders and $j = \{3,5\}$ jobs, and at the beginning of each auction every bidder was informed of his type for each job. One's type constitutes a fitness score for each job (i.e., how qualified is the bidder) and the bidder's reservation wage (i.e., his preference) for each job. Since fitness score is one component of each bidder's overall score for a job, high fitness scores signal potential monopoly power. Similarly, a low reservation wage indicates that the bidder "likes" a given job, so only that small amount will be subtracted from his bid when the payout is determined. All bidders knew the random selection procedure for both fitness scores and reservation wages. For each experimental design there were generally 20 auctions completed, but sometimes more if time permitted. Two sessions of each type were conducted, which generally yielded at least 40 rounds per experimental design. Each round the subjects either bid on three or five jobs.

For each of the j jobs in each round, the bidders were presented with their randomly selected fitness score and all the possible fitness scores from which the other bidders' fitness scores were randomly selected with replacement. As such, they were given some information about how qualified they were for each job relative to the likely qualifications of the other bidders. The predetermined fitness scores are represented by a $3 \times j$ matrix of fitness scores in which the columns represent each of the j available jobs. The rows represent the fitness scores randomly selected (with replacement) for each bidder.

$$\mathbf{F} = \begin{bmatrix} f_{1,1} & \cdots & f_{1,J} \\ \vdots & \ddots & \vdots \\ f_{3,1} & \cdots & f_{3,J} \end{bmatrix}$$

Each bidder was informed of his fitness scores but not those of the other bidders. He did, however, know all the possible fitness scores from which they were randomly selected (with replacement). This is intended to simulate the situation in which the bidder has only imperfect information with respect to his probable market power.

The predetermined reservation wages are represented by the following $10 \times j$ matrix, **C,** in which the columns represent each of the j available jobs. The rows represent the potential reservation wage sets, from which one is randomly selected for each bidder. This below matrix is shown to each bidder and the row indicating that bidder's values is highlighted.

$$\mathbf{C} = \begin{bmatrix} c_{1,1} & \cdots & c_{1,J} \\ \vdots & \ddots & \vdots \\ c_{10,1} & \cdots & c_{10,J} \end{bmatrix}$$

Thus, each bidder was informed of his reservation wages but not those of the other bidders. He did, however, know all the reservation wages from which they were randomly selected (with replacement). The within column variances for fitness scores and preferences were selected so that neither was the dominant factor behind the assignments.

Subjects' Payment Calculations

Initially, each bidder received an endowment ranging from $15 to $25 that could be lost or augmented, depending on the results of the auctions. In the first-price auction format, the subject's pay for an assignment to a particular job is a function of his bid and reservation wage for that job. $p_{ij} = (\alpha_{ij} - c_{ij})x_{ij}$ where p_{ij} is subject i's payment for job j; α_{ij} is subject i's award for job j; and c_{ij} is subject i's reservation wage for job j.

For first-price auctions $\alpha_{ij} \equiv b_{ij}$, where b_{ij} is the subject's bid. For a Modified VL auction, however, α_{ij} is a function of all the bids from all the other subjects. Once all bids have been submitted for all j jobs, the largest amount that the bidder could have bid, holding all other bids constant, and still have been assigned to that job is calculated. That amount constitutes α_{ij}. Since assignments are chosen so as to maximize the sum of total scores across the assignments, bidding lower on any given job increases the probability of assignment to that job but does not impact the subject's payment for that job.

In the high-contention auction experiments, there were three unassigned subjects and in the low-contention auction there was only one. In addition to the opportunity cost of being unassigned, an unassigned bidder incurred a small monetary penalty. This is intended to model the situation in which a Sailor, who is unassigned after several auctions, will be forcibly assigned to a job that generally is less desirable than many of the ones previously available. An example of one of the sets of instructions is included in the appendix.

Data

To account for improved level of task understanding, observations from auction rounds 10 through 20 for each experimental parameterization (i.e., contention level, bid-weight, and auction format) were used. For most cases, this was enough to eliminate any statistically significant trend in the data. Trends were identified using the following estimation:

$$\frac{\text{Bid}}{\text{RW}} = \hat{\beta}_0 + \hat{\beta}_1(\text{Auction Round \#}) + \varepsilon .$$

In some instances eliminating observations from the first 10 auction rounds was insufficient to reject Ho: $\beta_1 = 0$, and observations 15 through 25 were used instead. In the University of Memphis and University of Mississippi data, this was sufficient to eliminate all systematic trends toward more or less aggressive bidding strategies. In a few of the Southern Methodist University

(SMU) experiments, less than 20 auction rounds were conducted per experiment. In such cases observations from the last ten auction rounds that were conducted were used. In each case this successfully eliminated trends toward more or less aggressive bidding. In total, 900 observations were used in the estimation.

Experimental Results

This analysis focuses on the winning bids because some of the non-winning bids were simply "Hail Marys" in that the subject had no reasonable expectation of winning but wanted to at least have the possibility of winning a significant amount of money in that round. Since these types of bids only indirectly affect the auction, the best measure of overall efficiency of the auction environment is one based on the assigned jobs.

First vs. Modified VL Auction Formats

As expected and shown in Table 1, the Modified VL auction did induce the subjects to lower their bids closer to their reservation wages, but the decrease was insufficient to more than offset the post-bid increase in the award. As shown in the below table, for one set of experiments the reduction in the Bid/RW ranged from 2.6 to 24.6 percent. Despite these reductions in the bids, the payments were substantially higher for the Modified VL auctions than the first price auctions. The increases in payouts ranged from 8.3 to 81.5 percent. While only the 20 percent and 80 percent bid-weight experiments are presented in Table 1, the other experiments involving alternative bid-weights are qualitatively consistent with this result. In part, this increased payout associated with the Modified VL auction is due to the small (only 6) number of subjects that participated in the auction each round. The choice of six subjects per experiment was made in part due to the fact that in many instances, the number of Sailors bidding on a given job may be small. Since payouts may be substantially larger under this environment, the incentive structure of a Modified VL (i.e., "second" price) auction results in greater efficiency reductions when non-bid factors are considered than does a first-price sealed bid auction. While the VL assignment auction format offers an efficient auction mechanism when 100 percent weight is placed on the bid, relaxation of this assumption appears to negate this result in practice—at least when there are only a small number of bidders. The remainder of the analysis is limited to the identification of tradeoffs associated with alternative parameterizations of a first-price, sealed-bid auction.

Table 1
First to modified VL auction

% Change in Bid/RW and Payment		Bid-weight 20%	Bid-weight 80%
Contention: High	Bid/RW	-24.6%	-6.9%
	Payment	60.2%	81.5%
Contention: Low	Bid/RW	-2.6%	-22.3%
	Payment	70.6%	8.3%

Impact of Auction Parameterization on Winning Bids

In order to assess the impact of the auction parameters on the bidding behavior of the subjects, the Bid/RW ratio for all the winning bids is calculated. The first-price, low-contention auction is the most likely auction format to be implemented in the Navy and these results are presented first. For all first-price, low-contention auctions, the averages per experiment (generally 2 experiments of each parameterization were conducted) are plotted in Figure 1. So that they can be readily interpreted as the percentage of inefficiency in the bid (i.e., percentage above the subjects' reservation wages), the values presented are (Bid/RW – 1)*100. For example, a value of 100 would indicate that on average the bids exceeded the subjects' reservation wages by 100 percent.

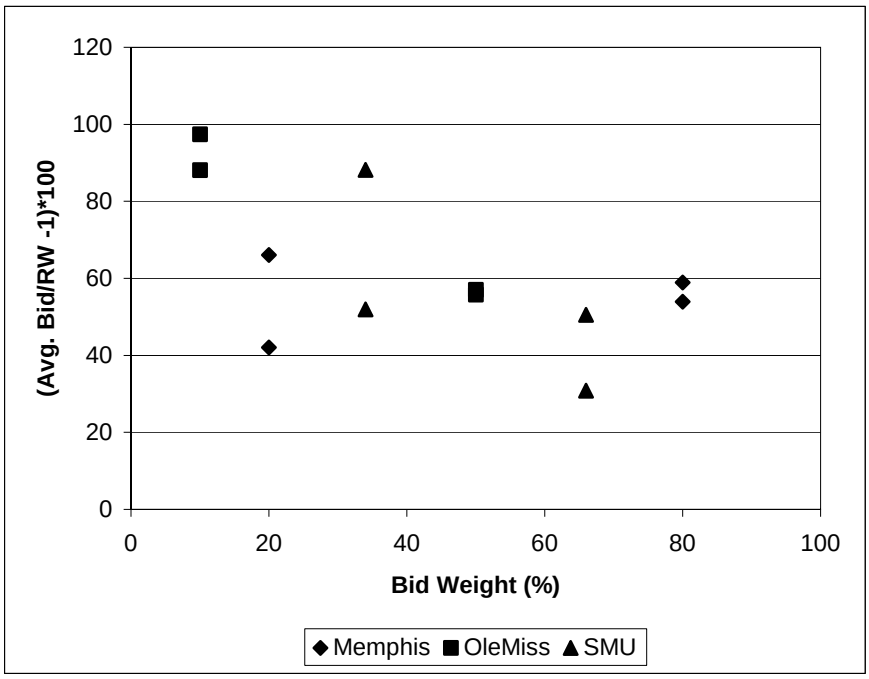

Figure 1. First-price, low-contention, winning bids.

As expected, a clear pattern emerges in which there is an inverse relationship between the normalized bids submitted and the weight attached to the bid. In cases where the bid-weight falls to only 10 percent, the bids submitted are nearly double their reservation wages. With a 66 percent bid-weight, however, on average bids only exceeded the subjects' reservation wages by approximately 40 percent (the average Bid/RW was 1.3 and 1.5 in the two experiments). To estimate more precisely the responsiveness of bids to changes in the bid-weight, we estimated the following regression.

$$\text{Bid} = \hat{\beta}_0 + \hat{\beta}_1\text{Contention} + \hat{\beta}_2\text{Memphis} + \hat{\beta}_3\text{Mississippi} + \hat{\beta}_4(\text{BidW})^{-1} + \hat{\beta}_5\text{RW} + \hat{\beta}_6\text{FS} + \varepsilon,$$

where *BidW* is the weight on the bid, and *Memphis* and *Mississippi* are dichotomous {0,1} dummy variables referencing the university at which the experiments were conducted. The university variables are intended to account for systematic differences in student populations that may affect bidding strategies. Contention indicates the degree of competition for the available jobs. The contention level equals 0.5 for high-contention auctions (3 jobs to 6 bidders or 1-3/6) and 0.167 for low-contention auctions (5 jobs to 6 bidders or 1-5/6). *RW* indicates the agent's reservation wage and *FS* indicates the agent's fitness score for each job. Table 2 presents the regression results for first-price auctions. The functional form is nonlinear in BidW because *a priori*, if uncapped, one would expect that the bids, and hence payments, would rapidly approach infinity as the BidW approached zero. Visual inspection of Figures 1 and 2 is consistent with this. In the data generated the lowest weight placed on the bids was 10 percent, and all winning bids were less than the maximum allowable bid.

Table 2
Dependent variable: payment

Rsquare = 0.316				
Independent Variables				
Intercept	**Contention**	**BidW^{-1}**	**Memphis**	**Mississippi**
1.18	-2.07	12.51	0.007	0.163
17.7***	12.3***	12.9***	0.11	2.18**

*** Indicates significance at the P value < 0.01 level.
** Indicates significance at the P value < 0.05 level.

Calculated at the mean values of the location, reservation wage, and fitness score variables, and a 50 percent bid-weight, the elasticity of the payment to changes in the bid-weight in a low-contention auction is $\varepsilon_{BidW,\,Bid} = -0.10$. At a bid-weight of 10 percent the elasticity rises to -0.35. While the response is certainly inelastic, over large ranges of the bid-weight, the level of the bids varies substantially. For example, the predicted values suggest that increasing the bid-weight from 10 percent to 50 percent results in a 28 percent reduction in the level of bids. Increasing the BidW further, however, provides diminishing reductions in the level of the bids.

Since high-contention auctions tend to reduce the submitted bids, one might hypothesize that bids would be less responsive to the bid-weight in a high-contention than in a low-contention auction. The idea being that the high-contention level has already substantively depressed them. This does not; however, appear to be the case. Figure 2 presents the effect of bid-weight on the Bid/RW ratio.

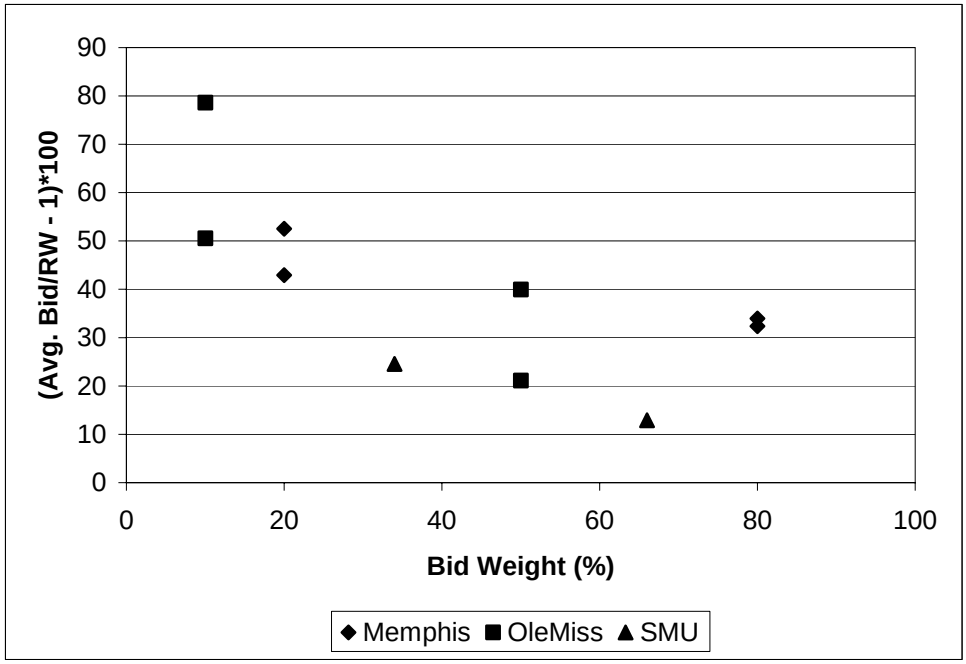

Figure 2. First-price, high-contention auctions (Bid/RW).

As expected there is an inverse relationship between the bid-weight and the bidding efficiency. Interestingly, casual observation suggests that in the high-contention auctions the submitted bids are at least as responsive to the bid-weight as in the low-contention environment. Indeed, the estimated elasticity when the bid-weight is 50 percent, $\varepsilon_{BidW,\ Bid}$ = -0.14, bears that out. The payment may even be slightly more responsive to bid-weight than in the low-contention environment. Changes in the contention level precipitate greater responses than changes in the bid-weight. Evaluated at the low contention level (5 jobs to 6 bidders), 50 percent bid-weight, and the mean values of the other variables, the estimated contention elasticity is $\varepsilon_{Contention,Bid}$ = -0.15. For high contention auctions (3 jobs to 6 bidders) the contention elasticity increases to $\varepsilon_{Contention,\ Bid}$ = -0.22.

Although combining a high-contention with a high bid-weight does substantially reduce the inherent inefficiencies (i.e., bids in excess of reservation wages), even the most efficient result (66% bid-weight and high-contention) resulted in submitted bids almost 13 percent in excess of the bidders' reservation wages. Given that the cost, in terms of the degradation of other measures of effectiveness, may be substantial, an organization may be more likely to select bid-weights closer to 50 percent. It is worth noting that at that level, the average bids in low-contention auctions were closer to 55 percent inefficient (the Bid/RW ratio averaged 1.56 in two low-contention experiments conducted). As such, deviations from traditional auctions in which 100 percent weight is placed on the bid, may substantially reduce the effectiveness of the auction approach to elicit bids near an agent's reservation wage. As such, the incentive-compatible bidding strategy diverges from the agent's reservation wage as the bid-weight diminishes.

Alternatively, one could ask how sensitive is the quality of the matches to the choice of bid-weight. The extent to which the optimization can then improve the overall fitness score, however, highly depends on the variation in the fitness scores.

Assessment of Market Power

This section analyzes the extent to which alternative auction design features tend to eliminate the ability of bidders to exercise market power associated with a high fitness score. For each parameterization of the auction, the below regression was estimated.

$$\text{Bid} = \hat{\beta}_0 + \hat{\beta}_1(\text{RW}) + \hat{\beta}_2(\text{Fitness}) + \varepsilon .$$

Table 3
Assessment of market power

Factors Limiting Market Power	Coefficient on the Fitness Score		
	Memphis	**Mississippi**	**SMU**
Modified VL	0.226	-0.025	0.121
	3.7***	-0.4	1.6
High-contention Only	0.279	0.02	0.0268
	2.8***	0.19	0.37
High Bid-weight Only	0.121	0.11	0.219
	3.5***	4.9***	3.08***
High Bid-weight and High-contention	-0.019	-0.079	0.043
	-0.2	-1.2	1.2

*** Indicates significance at the P value < 0.01 level.

A priori, one would expect that a Modified VL auction format, a high-contention level, and a high bid-weight would all be features that tend to reduce the opportunity of market participants to exploit market power associated with a high fitness score. While the Ho: $\hat{\beta}_0 = \hat{\beta}_2 = 0$ is almost everywhere rejected, the Ho: $\hat{\beta}_2 = 0$ is not. In Table 4, the Ho: $\hat{\beta}_2 = 0$ is tested. The parameter estimates and the associated t-statistics and significance levels are given for each regression. If the Ho is rejected, this suggests that the subjects may be increasing their bids when their fitness scores are relatively high to exploit their perceived market power. The above

regression was estimated separately for each school because the “high” and “low” bid-weights varied across locations. In two out of the three cases when the Modified VL auction format was the only market-power limiting factor, the Ho was not rejected and the bidders’ strategies did not appear to involve varying their bids proportionately with their fitness scores. Similarly, high-contention alone may be enough to generally deter the perception of market power, as the Ho was not rejected in two of the three cases. The same, however, cannot be said of a high bid-weight alone. Although Table 2 and Figures 1 and 2 clearly indicate that high bid-weights tend to lower bids, it appears that a high bid-weight (50–80%) alone is not enough to completely deter bidders from attempting to exploit their perceived market power when they are strong candidates. Combining a high bid-weight with a high-contention level, however, does eliminate the perception of market power.

Conclusions

The U.S. Navy envisions including a Sailor's bid as part of an overall objective function to be used to match Sailors to jobs. Since factors such as moving cost and qualifications must be considered in addition to the Sailor's bid, a number of questions arise as to the efficiency of such an auction format. The existing literature on assignment auctions is limited but Leonard (1983) and Olson and Porter (1994) provide seminal work in this literature. In this paper the authors relax the assumptions that all bidders are equally qualified, that 100 percent weight is placed on the bid, and that bidders are paying for assignments (as opposed to being paid for them). Since relaxation of these assumptions implies that no known mechanism will induce truth telling as an optimal bidding strategy, the authors empirically estimated the efficiency tradeoffs implied by reductions in the bid-weight. Significant premiums above the Sailor's reservation wage are likely without substantial weight being placed on the bid. As expected, the amount paid to the bidder varies inversely with bid-weight. In a low-contention, first-price auction with a 50 percent bid-weight, the estimated elasticity of payment to changes in the bid-weight is -0.10 but becomes -0.34 with a 10 percent bid-weight. Increasing the weight on the bid from 10 percent to 50 percent decreases the amount of the bids by an estimated 28 percent. Interestingly, with a high-contention environment the bid-weight elasticity is not diminished and is estimated to be -0.14 with a 50 percent bid-weight. Since high-contention auctions also tend to reduce the submitted bids, one might hypothesize that bids would be less responsive to bid-weight in a high-contention than a low-contention auction. The idea being that the high-contention level has already substantively depressed them. This does not, however, appear to be the case and even in high-contention auctions the additional bid reducing effect of increasing the bid-weight is retained.

It was hypothesized that a variant of the second price auction, a Modified Vickery-Leonard auction, might lower bids sufficiently enough to make it the least-cost auction mechanism for the auctioneer. While the bids submitted were generally lower, the payments were significantly higher. While a larger pool of bidders would lessen the increase in required payments, six bidders are clearly too few.

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Appendix

INSTRUCTIONS FOR AUCTION EXPERIMENTS

Introduction

You are about to participate in an experiment in which you will make decisions in an auction. Several auctions will be conducted but the exact number is unknown. You and 5 other participants (6 total) are gathered as candidates to fill 5 fictitious jobs. Whether or not you are selected for a particular job will in part depend on how qualified you are for the job (as expressed by a fitness score randomly generated by the software) and how willing you are to take the job (as expressed by how low your bid is for the job). The greater your bid for a job, the more money you will receive if you are selected for it. On other hand, bidding high for a job makes it less likely that the software will select you for that job. Bidding high on all jobs makes it more likely that you will be unassigned. Being unassigned means that not only do you not earn any money in that auction but you will also incur a penalty of $0.30. Exactly how your bids affect your assignment is explained below. Your task is to select a bid for a series of jobs.

We will first conduct a short experiment that does not involve monetary payouts so that you may first familiarize yourself with the procedure.

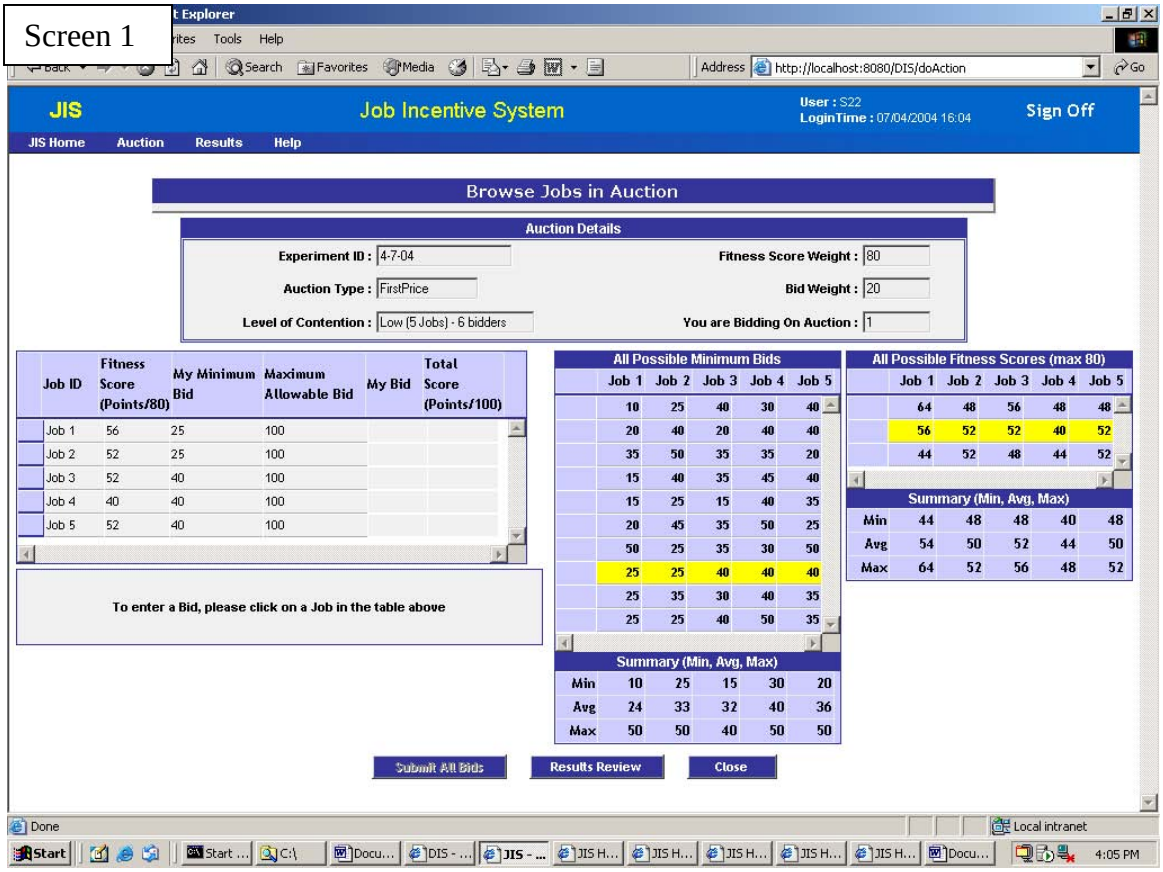
Your bids and profit in these auctions will be in terms of Gamebucks but you can convert them into U.S. Dollars at a rate of U.S. Dollars/Gamebuck = 0.10. In other words, if you were to earn 10 Gamebucks in profit you would earn $1.00 in U.S. Dollars. Any profits earned will be yours to keep.

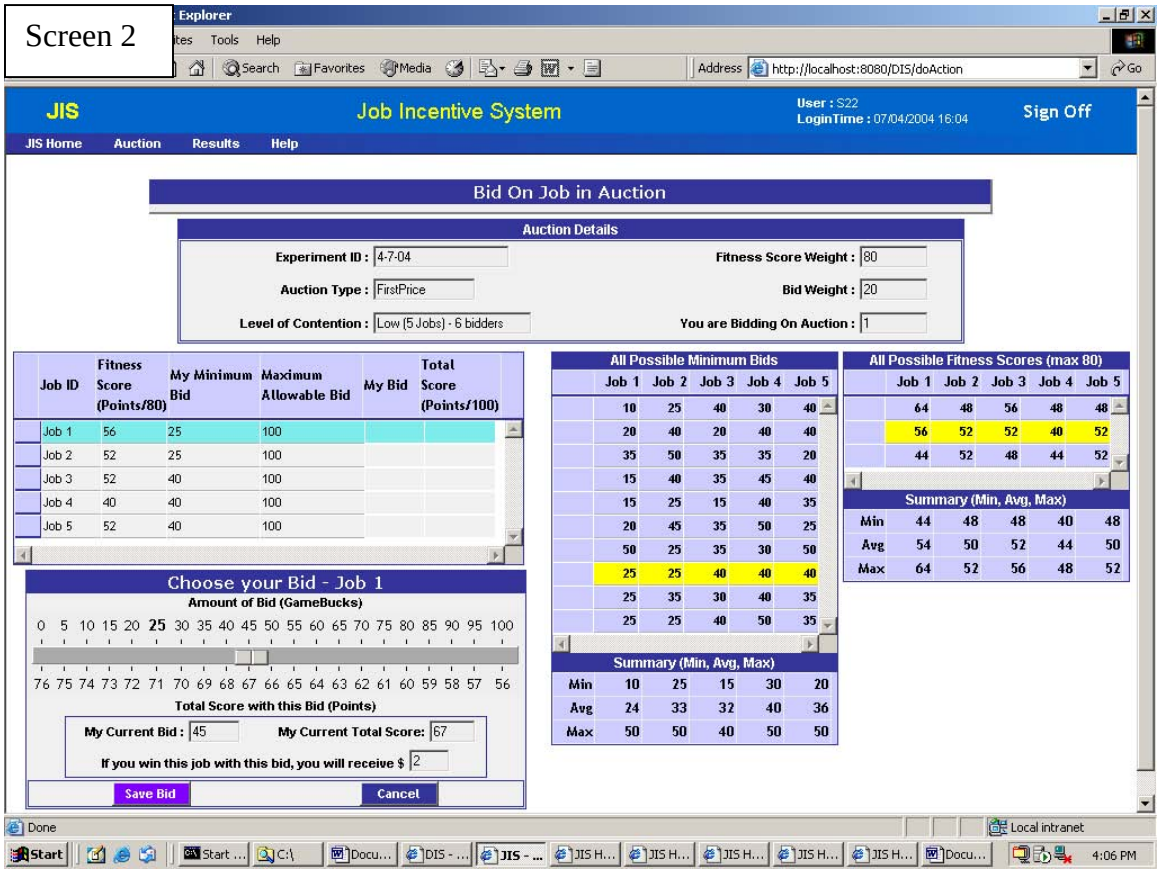
For your participation today you are guaranteed to leave this room with no less than $13, but you may earn more.

Experiments 1 and 1a

How to Bid on Jobs in the Auction

In the lower left hand box of Screen 1 you will see 5 jobs (i.e. Job 1, Job 2, Job 3, Job 4, and Job 5) on which you will bid. For example, to bid on Job 1 click on the row starting with Job 1. This will cause the bid calculator pop-up to appear as in Screen 2.





Screen 2 displays the same screen as in Screen 1 but now includes the bid calculator pop-up that will assist you in placing your bid for Job 1. As you move the scroll bar to the right, the bottom three boxes will indicate that bid's value in Gamebucks that that position of the scroll bar reflects, the corresponding Total Score (out of 100 possible points) that bid generates, and translate that bid in terms of U.S. Dollars that you would earn if you were to submit that bid and be assigned that job. Once you are satisfied with a particular bid, click on the "Save Bid" button and the pop-up bid calculator will disappear and you may select another job on which to bid. Once you have placed a bid on all the jobs and are satisfied with your bids, click on the "Submit All Bids" button displayed in Screen 1. At this point you must wait until all bids from the participants have been submitted and the results made available.

How Your Bids Affect Your Assignment

In each auction you will be presented with 5 jobs on which you may bid. You will be competing with 5 other bidders (6 total) for these jobs. Your Total Score affects your assignment. The higher your Bid, the lower is your Total Score. In each of the several auctions in which you participate, the weight on your Bid is 20% and the weight on your Fitness Score is 80%. This means that you may receive as many as 20 points for your bid and 80 points for your Fitness Score. The highest value that your Total Score could be is 100 points. If your Bid were 0 Gamebucks, then you will receive all 20 points for the bid component of your Total Score. On the other hand, if your bid were 100 Gamebucks, which is the maximum allowable number of Gamebucks, then you will receive 0 points toward your Total Score. The remaining 80 possible points come from your Fitness Score. You will be randomly assigned a number ranging from 0 to 80 for your Fitness Score for each job. This means that 4/5 of your Total Score is unaffected by your bid.

For each auction the software will then make the assignments that generate the maximum possible sum of Total Scores across all assignments. An illustrative example is given at the end.

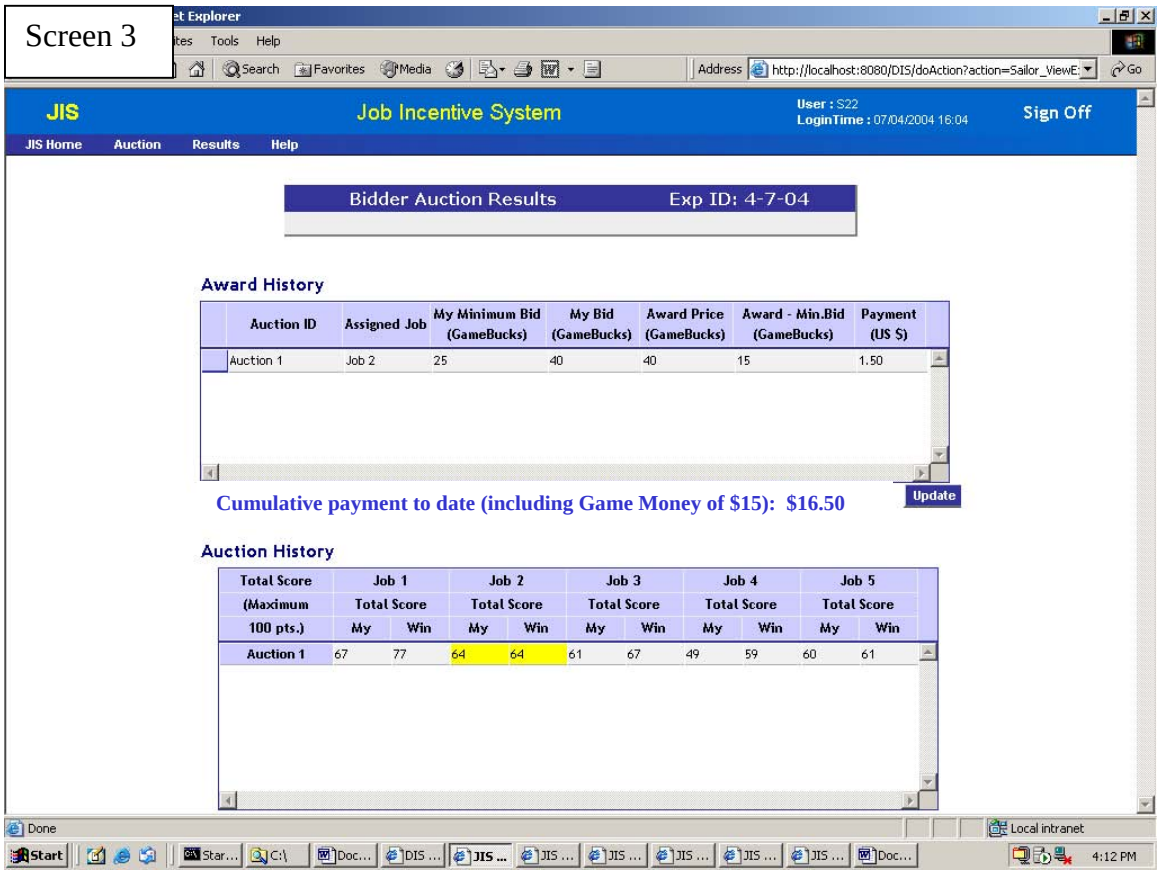
How Your Payments Are Calculated

You will receive $15 U.S. Dollars of Game Money that you may think of as "working capital" that you can either add to or lose in the following manner. Note that this $15 is already reflected in the "Cumulative payment to date (including Game Money)" figure tabulated at the end of each auction and displayed as in Screen 3. In the example case given, if all the auctions were completed, then your total payment for the auction experiment would be $16.50 (as indicated on Screen 3).

In each auction the Game Money may be added to or lost in the following manner. Suppose that based on the above calculations you have been assigned to Job 2 as shown in Screen 3. Furthermore, assume that your bid was 40 Gamebucks. Since your "My Minimum Bid" was 25 Gamebucks, that means that your profit is 15 Gamebucks (i.e. 40-25 = 15). You may exchange that profit in Gamebucks for U.S. Dollars at a rate of U.S. Dollar/Gambuck = 0.10. Thus, your earning from that auction is $1.50 (i.e. 0.10 x 15 = 1.50) in U.S. Dollars. As shown in Screen 3, after each auction the software will update your cumulative payment to date (including Game Money) in U.S. Dollars to reflect the outcome of the last auction.

On the other hand suppose that you were not assigned any job. In this case $0.30 will be subtracted from your cumulative payment to date figure as tabulated in Screen 3.

Bidding less than your "My Minimum Bid" is highly discouraged in this auction. If you bid below your "My Minimum Bid" this increases the likelihood that you will be assigned that job and if you were assigned that job you will lose money. For instance, if your bid were 20 Gamebucks and "My Minimum Bid" were 40 Gamebucks then you lose 20 Gamebucks or $2.00 U.S. Dollars (i.e. 20x0.10 = 2.00). In this case $2.00 (U.S. Dollars) is subtracted from your cumulative payment to date figure.



Information Provided to Inform Your Bids

On the right hand side of both Screens 1 and 2 for each of the 5 jobs you will see a table titled "All Possible Minimum Bids." This table indicates that for the 5 jobs in this auction there are 10 rows from which one row is randomly selected (with replacement) for each bidder. The row highlighted is the one randomly selected for you for this auction. In subsequent auctions another random selection will be made for you. Although you do not know the row that is selected for your competitors, you do know all the possible rows from which they are randomly drawn. Furthermore, for each job you know whether or not your "My Minimum Bid" is above or below the average of all possible values. For instance, you know that for Job 1, your "My Minimum Bid" is 25, which is slightly greater than the average of 24.

Similarly, on the right hand side of both Screens 1 and 2 for each of the 5 jobs you will see a table titled "All Possible Fitness Scores (max 80)." Recall that the Fitness Score contributes to your Total Score as well. Your randomly selected (with replacement) row is highlighted in yellow. Other bidders will also be given a randomly selected a row for their Fitness Scores. The other bidders' rows may be different than yours. Again, the averages for each job are presented at the bottom so that you have some idea whether your Fitness Score is likely to be better or worse than the average.

You may want to refer to this information when determining how to set your bids for each of the available jobs. From this information you may be able to draw some inferences about what your competitors' bids are likely to be. Since other participants' bids affect your assignment, this information may be helpful, but you are not required to refer to it when determining your bids.

How Assignments are Determined – A Simple Example

To illustrate how the software will select who is assigned to a particular job, and who is not assigned at all, let's take a simple 2-job, 3-bidder scenario. The below Table 1 indicates the 2 Total Scores for each of the 3 bidders.

Table 1

	Job 1	Job 2
Bidder 1's Total Score	60	62
Bidder 2's Total Score	50	50
Bidder 3's Total Score	30	55

Given that there are 3 bidders and 2 jobs, there are 6 possible ways to determine the Assignment Set. The software calculates the Sum of the Total Scores for all 6 possible sets of assignments and then picks the one with the largest Sum of the Total Scores. No bidder will be assigned to more than one job per auction. In case of a tie the Assignment Set is randomly selected from those that offer the largest Sum of the Total Scores.

Table 2

Assignment Set		Job 1 Total Score		Job 2 Total Score	Sum of the Total Scores
1	Bidder 1	60	Bidder 2	50	60+50 = 110
2	Bidder 1	60	Bidder 3	55	60+55 = 115
3	Bidder 2	50	Bidder 1	62	50+62 = 112
4	Bidder 2	50	Bidder 3	55	50+55 = 105
5	Bidder 3	30	Bidder 1	62	30+62 = 92
6	Bidder 3	30	Bidder 2	50	30+50 = 80

Table 2 displays the Sum of the Total Scores for all Assignment Sets and highlights Assignment Set 2 as that is the one that generates the largest Sum of the Total Scores (60 + 55 = 115). Accordingly, Bidder 1 is assigned to Job 1, Bidder 2 is unassigned, and Bidder 3 is assigned to Job 2.

Payout in the Event of a Major Software Malfunction

This software has been tested extensively but in the event of a software malfunction that precludes the determination of the your proper payout, then you will be given $30 for your participation. The determination of whether there has been a major software malfunction will be made by the experiment administrators.

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