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Abstract

Tug-of-war is a multi-battle contest often used to describe extended interactions in economics, management, political science, and other disciplines. While there has been some theoretical work, there is scant empirical evidence regarding behavior in a tug-of-war game. To the best of our knowledge, this paper provides the first experimental study of the tug-of-war. The results show notable deviations of behavior from theory. In the first battle of the tug-of-war, subjects exert fewer resources, while in the follow-up battles, they exert more resources than predicted. Also, contrary to the theoretical prediction, resource expenditures tend to increase in the duration of the tug-of-war. Finally, extending the margin necessary to win the tug-of-war causes more discouragement than either a reduction in the prize or greater impatience despite all three having the same expected effect. Potential behavioral explanations for these findings are also discussed.

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1. Introduction

Ultimate success or failure in a competition often depends on the outcomes in a sequence of intermediate contests. In a patent race, companies exert costly resources at multiple stages and one company may drop out if it falls too far behind its rival. In a political contest, politicians engage in a series of debates and issue multiple policy statements in order to swing voters to their side. Similarly, in organizations, the final decision of a committee depends on the series of small arguments made by advocates who may go back and forth in trying to lobby their interests. These, and many other competitions, can be described as a "tug-of-war."

Most commonly, the term "tug-of-war" refers to a rope pulling contest in which two contestants (or groups) pull a rope in different directions until one of the contestants pulls the other across the middle. More generally, tug-of-war can be described as a contest consisting of a series of battles, where a battle victory of one contestant moves the game closer to the winner's preferred terminal state, and where one contestant wins the war if the difference in the number of battle victories exceeds some threshold (Konrad and Kovenock, 2005). As a modeling device, the tug-of-war has a large number of applications in economics (Harris and Vickers, 1987), management (Schutten et al., 1996), political science (Whitford, 2005), history (Organski and Lust-Okar, 1997), biology (Zhou et al., 2004), and other disciplines.

Harris and Vickers (1987) were the first to formally examine the tug-of-war game. They analyzed an R&D race as a tug-of-war in which two players engage in a series of multiple battles and the winner of each battle is determined probabilistically. The assumptions of their model, prevented Harris and Vickers from completely solving the model, and instead they were only able to obtain qualitative predictions. More recently, Konrad and Kovenock (2005) have explicitly solved the tug-of-war game and provided conditions for a unique equilibrium.[1] They showed that the contest effort crucially depends on the number of needed victories, the value of the prize, and the discount rate.

To the best of our knowledge, this is the first study examining tug-of-war experimentally. Our experiment examines the theoretical predictions of Konrad and Kovenock (2005), using a three-by-one between-subjects design. In the *Low Value* treatment, the value of the prize v, is lower than in the other treatments. The *Extended* treatment involves more possible states m and thus a greater necessary margin for victory, than the other two treatments. The *Impatient* treatment, reduces the discount rate δ as compared to the other treatments. We follow the standard procedure for inducing a discount rate by making continuation to the next round probabilistic (see Dal Bo, 2005; Duffy, 2008). The key aspect of the design is that for all three treatments $\delta^{m/2}v$ is fixed, which makes all three treatments theoretically equivalent. The prediction is that contestants should exert costly efforts (bids) in the first battle (round) using a mixed strategy as in the standard all-pay auction. In the follow-up rounds, when the state is not $m/2$, there should be no bidding. Moreover, bidding should not depend on the number of times a particular state has been reached. Finally, the aggregate behavior in each treatment should be the same as long as $\delta^{m/2}v$ is fixed.

We find notable deviations of behavior from theoretical predictions. First, we find that in the first round of the tug-of-war, bids are not drawn from the uniform distribution but are left-skewed, indicating underbidding. Second, we find that bids are systematically greater than the predicted value of zero in the follow-up rounds. Third, contrary to the theoretical prediction, conditional on the state bids tend to increase in the duration of the tug-of-war. Finally, we find that bidding behavior is similar in the *Low Value* and *Impatient* treatments, but bidding is significantly

[1] Also see Agastya and McAfee (2006).

lower in the *Extended* treatment, suggesting that extending the necessary margin of victory for the tug-of-war discourages subjects more from exerting resources than the lower prize or discounting.

The most closely related studies examine behavior in sequential multi-battle contests, also known as best-of-*n* races.[2] Mago et al. (2013), for example, examine behavior in a best-of-three race between two contestants and find that the leader exerts more effort than the follower. Zizzo (2002) implements a best-of-*n* race and finds a positive correlation between investment and progress in the race. Ryvkin (2011) investigates a best-of-*n* contest in which players who choose the high effort early in the competition decrease their probability of winning in later battles, imitating fatigue. Consistent with the theory, subjects abstain from high effort in early battles in the presence of fatigue. Deck and Sheremeta (2012) examine behavior in a multi-battle contest in which the defender must win each battle to secure the resource and the attacker needs only to win one battle to capture the resource. In the experiment, subjects' behavior is consistent with the main qualitative prediction of the theory, except for one key pattern: when fighting, rather than lowering expected effort in each new battle, subjects increase effort. Finally, Gelder and Kovenock (2015) examine behavior in a multi-battle contest with a losing penalty, and also find escalation of conflict effort contrary to the theoretical predictions.

Our study differs substantially from the previous studies. Most importantly, we examine behavior in the tug-of-war, which has not been previously studied in the literature (Dechenaux et al., 2015). The tug-of-war differs from the best-of-*n* race because in the race the number of battles *n* is fixed and the winner is determined by the number of battles each player has won. In contrast,

[2] There are also some studies on simultaneous multi-battle contests (also known as Colonel Blotto games), examining how different factors such as budget constraint, information, contest success function, asymmetry in resources and battles impact individual behavior (Avrahami and Kareev, 2009; Horta-Vallve and Llorente-Saguer, 2010; Kovenock et al., 2010; Arad, 2012; Arad and Rubinstein, 2012; Chowdhury et al., 2013; Mago and Sheremeta, 2014; Irfanoglu et al., 2015), as well as, studies on multi-battle elimination contests (Parco et al., 2005; Amegashie et al., 2007; Sheremeta, 2010a, 2010b; Altmann et al., 2012; Höchtl et al., 2015).

in the tug-of-war the first player to win $m/2$ (where m is even) more contests than her rival is the winner. In our experiment, the tug-of-war may continue for a very long time (infinity in the limit), potentially making it a very exhausting competition.

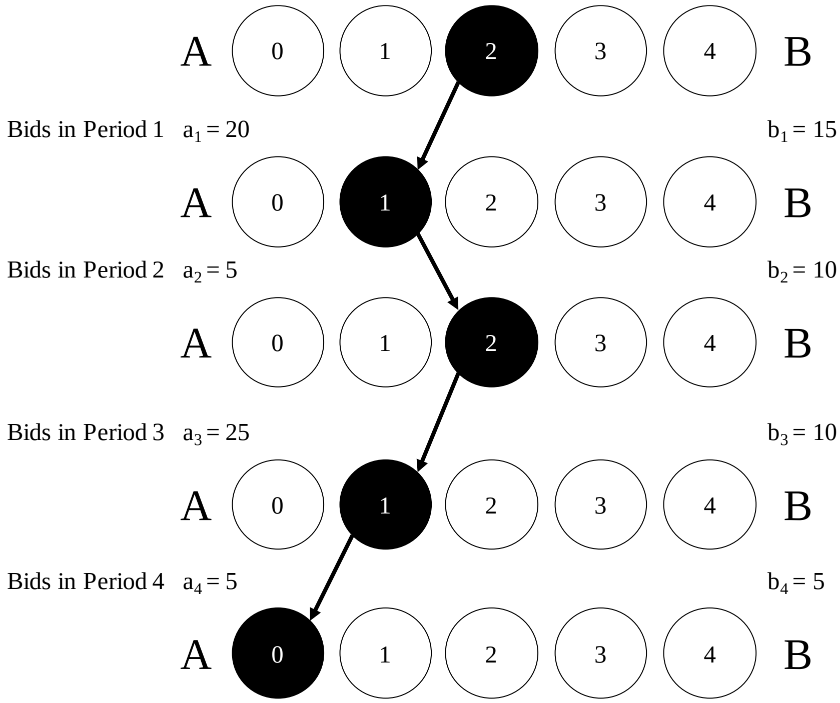
2. Theory and Hypotheses

2.1. The Tug-of-War Game

The experiment closely aligns with the theoretical model of Konrad and Kovenock (2005).[3] There are two players: A and B. There are $m+1 > 2$ ordered possible states (where m is even) located on the grid line along which the war can take place. Let x_t denote the state of the game at the start of round $t \in [1, 2, 3, \ldots]$. The tug-of-war begins in round $t = 1$ in the initial state $x_1 = m/2$, halfway between the two terminal states. At each round in which the game has not yet reached a terminal state, there is a contest resolved as an all-pay auction (Baye et al., 1996) where A's bid is denoted by $a_t \geq 0$ and B's bid is denoted by $b_t \geq 0$. If $a_t >$ (or $<$) b_t then A (or B) wins the contest and the state becomes x_t-1 (or x_t+). If $a_t = b_t$ then A wins if $x_t < m/2$, B wins if $x_t > m/2$, and the winner is determined randomly if $x_t = m/2$. If the game reaches state 0 (or m) then the game ends and A (B) claims a prize of v. Otherwise the game continues to the next round with the state in round t+1 determined by x_t and the outcome of the contest in round t. The two players are assumed to have a common discount rate of δ. Figure 1 shows an example of the game with $m = 4$ in which A wins after the fourth round. In this example, A earns v-55 and B earns -40.

[3] The model of Konrad and Kovenock (2005) is more general than what is presented here. We are only providing the detail needed for analyzing the specific situations we study in the laboratory.

Figure 1: An Example Tug-Of-War



The unique Markov perfect equilibrium is $a_t = b_t = 0$ if $x_t \in [1, 2, \ldots, m\text{-}1] \setminus \{m/2\}$ and a_t, b_t are drawn from the distribution $F(b)$ if $x_t = m/2$, where $F(b) = \begin{cases} \frac{b}{\delta^{m/2} v} & \text{for} \quad b \leq \delta^{m/2} v \\ 1 & \text{for} \quad b > \delta^{m/2} v \end{cases}$.[4] Intuitively, when the players are even (at state $m/2$), they are in an all-pay auction and the expected payoff to each player is 0. If the game is at state $m/2$-1, then a winning bid by *B* will move the game to a point in which *B* expects to earn 0, so *B*'s optimal bid is 0 and given the tie breaking rule *A* should bid 0 as well. Iterating this logic, *B* should never bid when the state is less than $m/2$ and similarly *A* should never bid if the state exceeds $m/2$. Because of the behavior that should occur when the state is not $m/2$, winning in the first round should result in winning the game in $m/2$ rounds making the prize for winning the first round $\delta^{m/2}v$.

[4] For the details see Proposition 3 in Konrad and Kovenock (2005).

2.2. Hypotheses

The equilibrium solution provides the basis for the hypotheses to be tested in the laboratory. Specifically, we test the following hypotheses regarding the expected behavior in a tug-of-war.

***Hypothesis* 1:** When the game begins (at state $m/2$), a player's bid is drawn from the uniform distribution over the interval $[0, \delta^{m/2}v]$.

***Hypothesis* 2:** When the state is not $m/2$, subjects bid zero.

The model also provides predictions regarding different tug-of-war games. In particular, if two tug-of-war games have the same value for $\delta^{m/2}v$ then behavior should be identical at state $m/2$. This leads to the following prediction.

***Hypothesis* 3:** Behavior does not differ between games with differing values of m, δ, and v if $\delta^{m/2}v$ is held constant.

While no state is predicted to be reached multiple times during a game; should such an event occur due to out of equilibrium behavior, behavior in that situation should depend on the state and not the round. This leads to our final hypothesis.

***Hypothesis* 4:** Play in a state does not depend on the round.

3. Experimental Design and Procedures

To test the hypotheses we conduct a three-by-one between-subjects experimental design. The three treatments (*Low Value*, *Impatient*, and *Extended*) differ in terms of the values of v, δ, and m as shown in Table 1. In the *Low Value* treatment, the value of the prize, v, is lower than in the other treatments. The *Extended* treatment involves more possible states, m, than the other two treatments. The *Impatient* treatment, reduces the discount rate δ as compared to the other treatments. We follow the standard procedure for inducing a discount rate by making continuation to the next round probabilistic (see Dal Bo, 2005; Duffy, 2008). Our primary goal is not to identify how changes in a specific variable impact behavior, but rather to determine if strategic behavior is contingent upon $\delta^{m/2}v$, as predicted by the theory. Hence, the key aspect of our design is that for all three treatments $\delta^{m/2}v$ is held constant (at ≈ 66). Although our design does not compare two treatments differing along a single dimension, one can identify the relative effects of specific parameters by comparing one treatment to the composition of the other two.

Table 1: Experimental Treatments

Treatment	m	δ	v
Low Value	4	0.81	100
Impatient	4	0.73	125
Extended	6	0.81	125

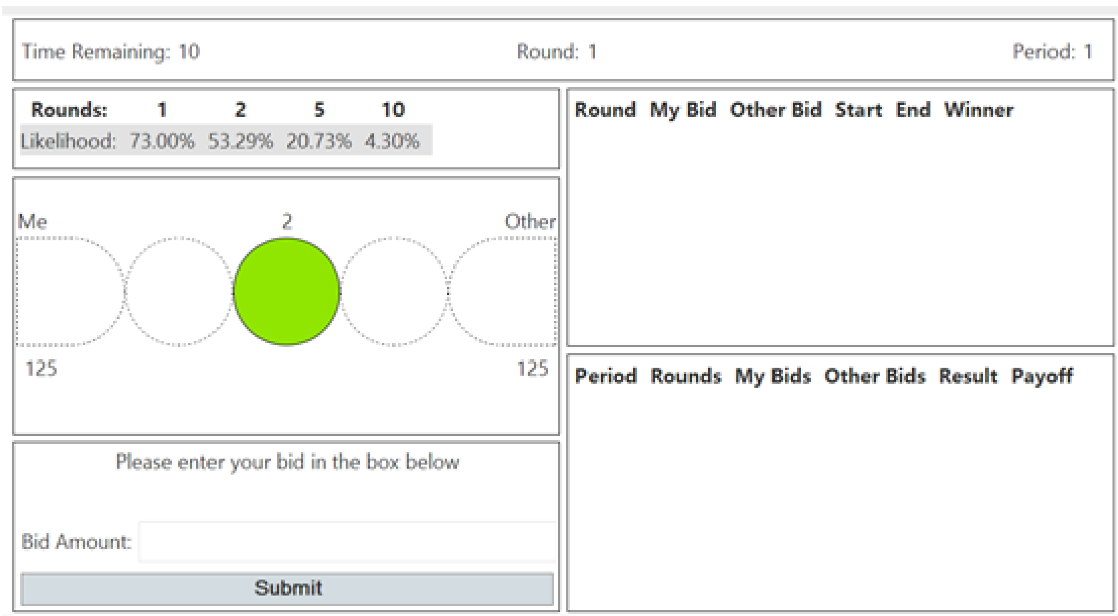
A total of 96 subjects participated in the experiment, which was conducted in the Behavioral Business Research Laboratory at the University of Arkansas. Subjects for each one hour long session were recruited through the lab's database of volunteers and no subject participated in more than one session. For each of the three treatments, four sessions were completed. Each session involved 8 subjects who read written instructions (available in Appendix) and completed a comprehension worksheet. After the worksheets were checked for correctness and any remaining questions were answered, subjects completed two unpaid practice tug-of-war games, and then ten salient tug-of-war games.

Each game, referred to as a period in the experiment, subjects were randomly and anonymously paired with someone else in the session.[5] Figure 2 provides a screen shot for the *Impatient* treatment. Subjects always saw themselves as the player who won the game at state 0

[5] The directions used the term tug-of-war in an effort to help subjects understand the nature of the game being played. Copies of the directions are available upon request.

on the far left of the screen as shown in Figure 2. The colored ball moved around based on the state of the game. The probability that the game would continue for one, two, five and ten more rounds if a terminal state was not reached is shown at the top left of the screen. The right hand portion of the screen records what has occurred in each round of the current period (game) and the outcome from previous periods.

Figure 2: Sample Screen Shot in Impatient Treatment

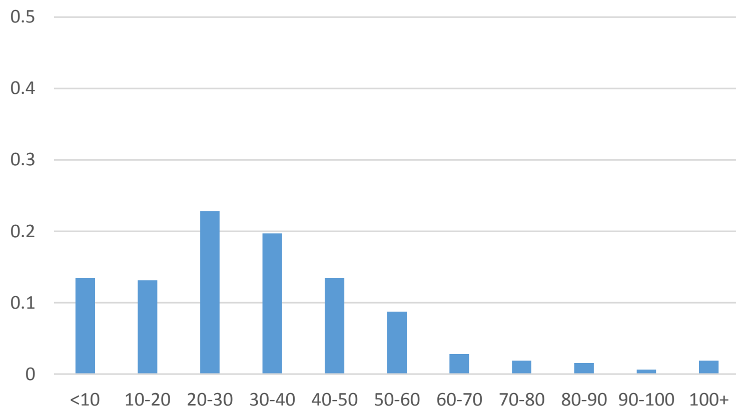


After all 10 periods were completed, one was randomly selected and subjects were paid their earnings based on the outcome of the game in that period. Experimental earnings were denoted in franks and converted into dollars at the rate 25 franks = $1. The average subject payment was $19.59.

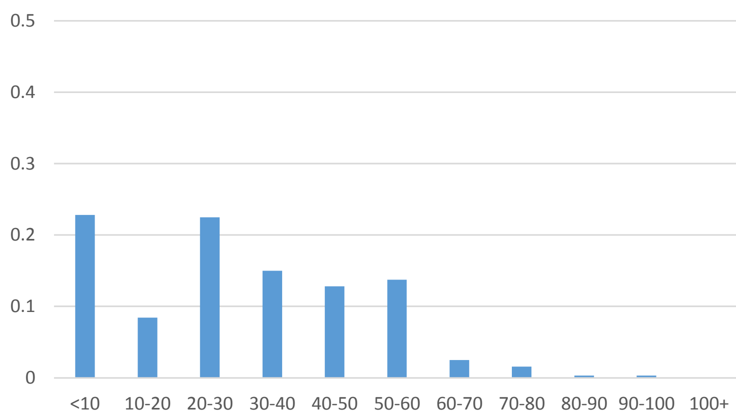
4. Results

The findings are presented as a series of results corresponding to the four hypotheses provided in the previous section. Figure 3 shows the distribution of bids in the first round of every tug-of-war by treatment.

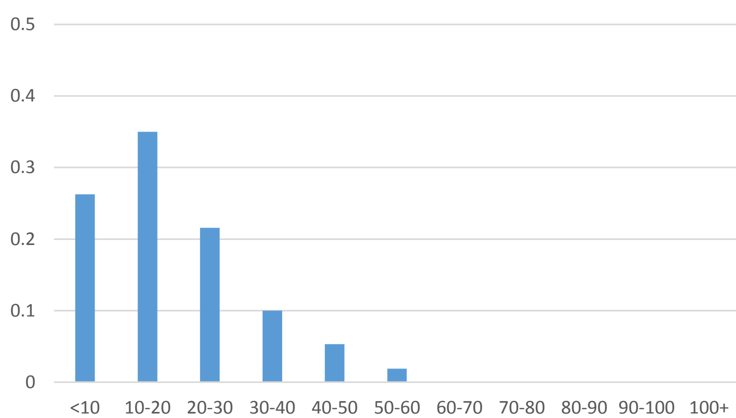
Figure 3: Distribution of Bids in First Round by Treatment



Panel A. *Low Value* Treatment



Panel B. *Impatient* Treatment



Panel C. *Extended* Treatment

Theory predicts that all bids should be distributed between 0 and 66 (= $\delta^{m/2}v$). Indeed, we find that by and large the bids are drawn from the same support as the equilibrium distribution. However, none of these distributions appear to be uniform over the interval 0 to 66. Statistically, we test that the mean and variance of each distribution is equal to the values that would be generated if subjects were behaving according to the theoretical predictions. Notice, that under the null hypotheses subjects are independently drawing their bids from the interval [0, 66] at the start of every tug-of-war. For each treatment, either the observed mean, the observed variance, or both differ from the theoretical predictions as shown in Table 2.

Table 2: Statistical Comparison of Observed and Predicted Behavior in the First Round

	Treatment		
Test of	*Low Value*	*Impatient*	*Extended*
Mean (t)	p-value = 0.190	p-value < 0.001	p-value < 0.001
Variance (χ^2)	p-value < 0.001	p-value = 0.138	p-value < 0.001

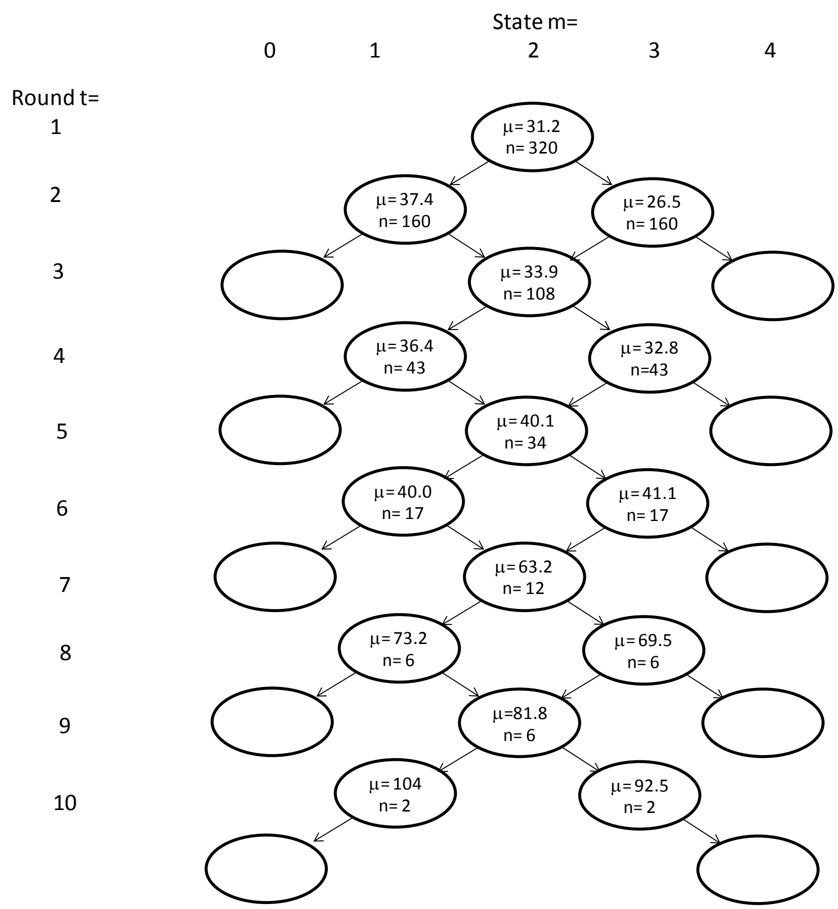
Interestingly, bids are skewed to the left, indicating underbidding. However, only for the *Impatient* treatment and the *Extended* treatment, the average bid is significantly lower than the theoretical prediction: 27.8 versus 33 (p-value < 0.001) and 16.8 versus 33 (p-value < 0.001), respectively. Overall, these findings provide evidence against Hypotheses 1 and are the basis for our Result 1.

***Result* 1:** *Subjects do not bid according to the theoretical prediction in the first round of a tug-of war. That is bids are not drawn from the uniform distribution over the interval [0, 66] and are skewed to the left.*

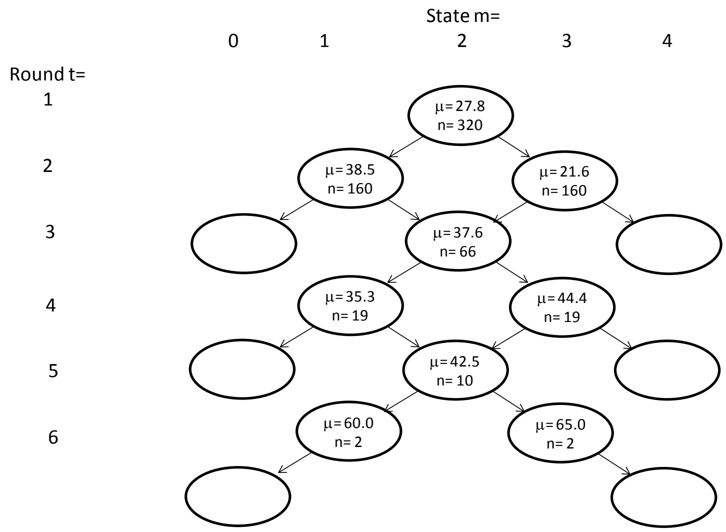
Another prediction of the theory is that when the state is not $m/2$, subjects should bid zero. However, we find that in the second round bids are systematically greater than the predicted value of zero. Only 3% of all bids at state 1 in the *Low Value* treatment are 0 and only 20% of the bids at state 3 are 0 in that treatment. For the *Impatience* treatment the respective percentages are 1% and 29% for states 1 and 3. The percentage of bids equal to zero for states 1, 2, 4, and 5 in the *Extended* treatment are 4%, 3%, 32%, and 41% respectively. Figure 4 shows the average bid by round and state for each treatment. Notice that when one player is in the state *x* the other player is in the state *m*-*x*. Also, because continuation to the next round is probabilistic, some pairs do not reach the terminal state nor do they reach the next round. The data in Figure 4 are taken to be sufficient evidence against Hypothesis 2.

***Result* 2:** *When the game is not in a symmetric state, subjects do not bid zero contrary to the theoretical prediction.*

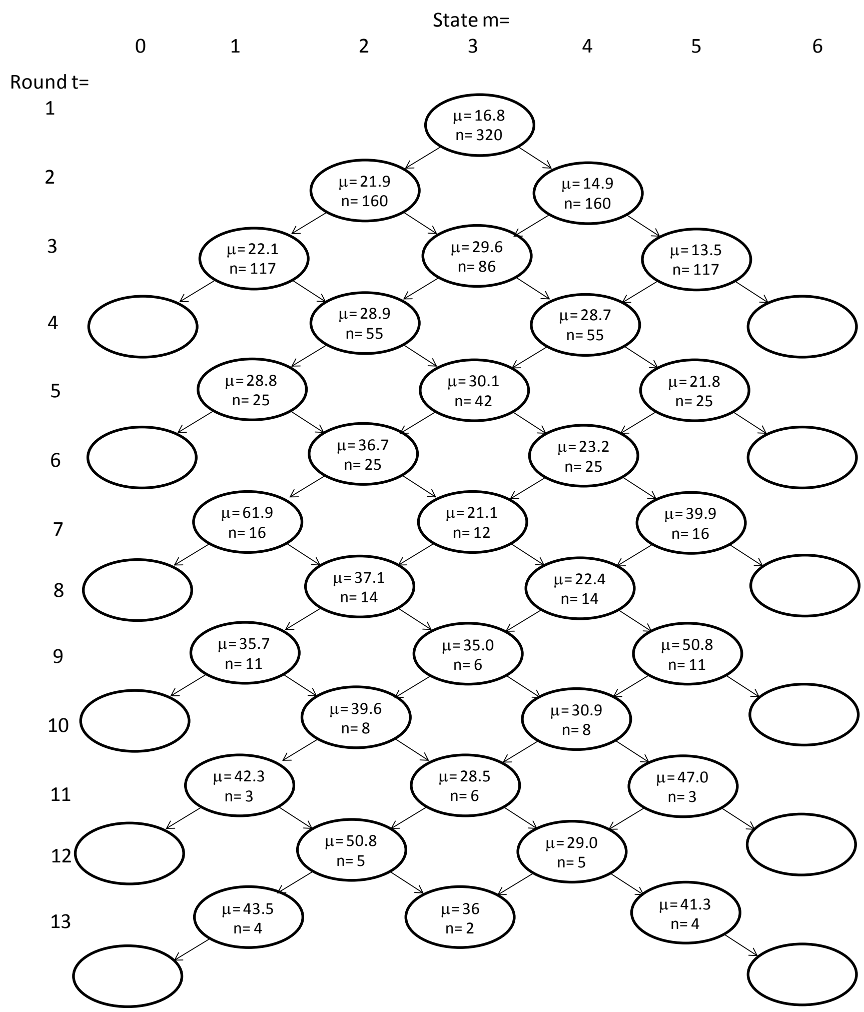
Figure 4: Average Bids by State and Round for Each Treatment



Panel A. *Low Value* Treatment



Panel B. *Impatient* Treatment



Panel C. *Extended* Treatment

Turning to the question of whether or not subjects behave the same in each treatment, we note that Figure 3 and Figure 4 suggest that bids are lower in the *Extended* treatment than the other two treatments. This conclusion is supported statistically in Table 3. The first column of Table 3 estimates how bids are impacted by treatments when the state is $m/2$. The omitted treatment is *Low Value* so the lack of significance for *Impatient* suggests these two treatments yield similar behavior on average. The negative and significant coefficient for *Expanded* indicates that on average bids are lower in this treatment than in the *Low Value* treatment. Average bids are marginally lower in the *Extended* treatment than in the *Impatient* treatment (p-value = 0.052). The second and third columns of Table 3 compare *Impatient* to *Low Value* at states 1 and 3, respectively, omitting *Extended* because 1) it has already been shown to differ and 2) the states are not directly comparable. For both specifications, the coefficient on *Impatient* is not significant. Together, these three specifications indicate that behavior is similar in the *Low Value* and *Impatient* treatments. This provides the support for Result 3.

***Result* 3:** *Bidding behavior is similar in the Low Value and Impatient treatments, but bidding behavior in the Extended treatment differs from the other two. In particular, subjects bid less in the middle state when there are more states in the tug-of-war.*

Table 3: Comparison of Treatments Conditional on State

	State = $m/2$	State = 1	State = 3
Constant	33.89***	38.91***	30.47***
Impatient	-4.06*	-0.47	-6.00
Extended	-13.00**		
Observations	1350	409	409

*, ** and *** indicate significance at the 10%, 5%, and 1% level respectively based on a two sided test. Standard errors are clustered at the session level.

Figure 4 also reveals another stark pattern in the data. Regardless of treatment, conditional on the state, bids tend to increase the longer the tug-of-war has been going. For all 11 treatment-state combinations, the average bid is lower in the earliest round in which the state was reached than in the latest round in which the state was reached. Table 4 provides statistical evidence of the period trend in each situation. For both the *Low Value* and *Extended* treatments, the trend is positive and significant. The trend is not significant in the *Impatient* treatment; however, one should be cautious given the relatively small number of observations occurring after round 3 in this treatment. These patterns lead to Result 4.

***Result* 4:** *Contrary to the theoretical prediction that bids are state independent, conditional on the treatment and state bids are generally increasing in the duration of the tug-of-war.*

Table 4: Estimation of Trend in Bids over Rounds Given Treatment and State

	Treatment		
	Low Value	*Impatient*	*Extended*
State 1	28.63***	37.19***	12.61***
State 1 × Round	3.54***	0.57	3.58***
State 2	26.04***	23.55***	16.85***
State 2 × Round	3.96***	4.38	2.77***
State 3	14.46*	-0.85	16.24***
State 3 × Round	5.51***	11.2	2.18**
State 4			13.16**
State 4 × Round			1.84***
State 5			-0.04
State 5 × Round			4.71***

*, **, and *** indicate significance at the 10%, 5%, and 1% level respectively based on a two sided test. Standard errors are clustered at the session level. Based on 3054 observations.

5. Discussion

Taken together, our findings provide substantial evidence of behavioral deviations from theoretical predictions. Here, we provide a discussion of these deviations and suggest some potential explanations.

We begin with Result 1. Contrary to the prediction that the first round of the tug-of-war should resemble a one stage all-pay auction, we find that bids are not drawn from the uniform distribution but are left-skewed. This finding is surprising given the vast experimental literature documenting overbidding, not underbidding, in all-pay auctions (Dechenaux et al., 2015). It is possible that the reason for this finding is that our experiment does not involve a one-shot all-pay auction, but rather a series of potentially many all-pay auctions which may prevent subjects from fully engaging in the very first round of the tug-of-war. The significant underbidding in the first round also can be interpreted as a "proper response" to the observation that most of the competition occurs in later rounds, as opposed to the predicted "frontloaded" competition. Since successful participation in later rounds requires substantial bids, it seems prudent to conserve resources in the first round.

Results 2 documents that bids in the follow-up rounds are higher than the predicted bid of zero. One natural explanation of this finding is that the prediction is at the boundary. The problem of boundary equilibrium predictions has been well recognized in dictator games (List, 2007), public good games (Laury and Holt, 2008), and contests (Kimbrough et al., 2014), and it has been proposed as an explanation for excessive giving, overcontribution to public goods, and excessive conflict. Similar argument can be used to explain our Result 2. The prediction is that subjects should bid zero after the first round, and any mistake that they make would lead to overbidding. Another explanation is that in addition to monetary prize, subjects also have a nonpecuniary utility of winning (Sheremeta, 2013, 2015; Price and Sheremeta, 2011, 2015). In such a case, subjects may continue to participate in the tug-of-war even if their continuation value is zero. Such a utility inherently transforms the game into a multi-battle contest with intermediate prizes; and one of the fundamental theoretical results with intermediate prizes is that "the player who is lagging behind may catch up, and does catch up with a considerable probability in the equilibrium" (Konrad and Kovenock, 2009, page 267). Both these explanations are consistent with our findings.

Result 3 documents that bidding behavior in the *Extended* treatment is significantly different from the *Low Value* and *Impatient* treatments, despite all three treatments being theoretically equivalent. One explanation for this result is that subjects are discouraged by a potentially long and exhaustive tug-of-war in the *Extended* treatment. Another explanation is that subjects apply a multi-dimensional reasoning when choosing their strategies in the tug-of-war (Arad and Rubinstein, 2012). Specifically, subjects first decide how much they are willing to spend on the tug-of-war and then they choose how to allocate these resources across the rounds. At the start of the tug-of-war, the best case scenario is winning the first $m/2$ rounds and claiming the prize – a path along the top left edge of flow charts in Figure 4. For all three treatments, the sum of the average bid along the best case scenario path is similar (68.6 in *Low Value*, 66.3 in *Impatient*, and 60.8 in *Extended*). Further, along each best case scenario path the average bids are fairly uniform. This suggests that subjects may begin by thinking about how much they want to spend along the path they hope to take and then allocating their resources more or less evenly along that path. As a result, bids at specific states along the best path in the *Extended* treatment are smaller than in the other treatments because the same amount of resources is being divided over more states. As subjects win and remain on the best case scenario path, they continue to implement their plan. Once they are knocked of the best scenario path, they adjust as evidenced by Result 4.

There are two possible explanations for Result 4 that bids increase in the duration of the tug-of-war. One is that people who compete more intensively are simply more likely to reach later rounds and the other is that individuals engage in bid escalation as the game progresses. Further examination of the data suggests that it is the later. Consider the *Low Value* treatment. When a bid is placed in round 7, on average the bid in that round is 21.5 greater than the bid that the same contestant made in round 1. We reject the null hypothesis that the change from round 1 to round 7 is equally likely to be positive or negative in favor of the alternative hypothesis that bids are increasing (sign test, p-value = 0.022). For the *Impatience* treatment, when someone reaches round 5 the average increase from that person's round 1 bid is 16 (sign test, p-value = 0.063). For the contestants who returned to the middle state in round 9 of the *Extended* treatment, the average bid increase from round 1 is 15.3 (sign test, p-value = 0.031). Similar patterns arise in other comparisons; however, one needs to be cautious as a pair that goes several rounds may only arrive at a state once. Thus, Result 4 provides evidence of conflict escalation, i.e., conditional on the state bids tend to increase in the duration of the tug-of-war. Although this finding is contrary to the theoretical prediction, it is consistent with a well-documented escalation of commitment (Staw, 1976).

6. Conclusion

Tug-of-war is a multi-battle contest used to model extended interactions in economics, management, political science, and other disciplines. It has attracted the attention of prominent theorists (Harris and Vickers, 1987; Konrad and Kovenock, 2005; Agastya and McAfee, 2006), but to the best of our knowledge there are no previous experimental tests of a tug-of-war (Dechenaux et al., 2015).

Our results show notable deviations of behavior from theory. In the first battle of the tug-of-war, subjects exert fewer, while in the follow-up battles, they exert more resources than predicted. Also, contrary to the theoretical prediction, resource expenditures tend to increase the longer the tug-of-war has been going. Finally, we find that the required margin of victory of the tug-of-war influences subjects more from exerting resources than the value of the prize or discounting.

Our findings have implications both for theorists and practitioners. The fact that in all treatments subjects shift their resource expenditures from the first battle to the later battles suggests that there are important factors which are not captured by the theory. We conjecture that some of these factors include bounded rationality and nonpecuniary incentives, both of which could be incorporated into the tug-of-war model. From practical point of view, our findings show that conflicts resembling the tug-of-war game may be more extensive than predicted. At the same time, potentially long conflicts may deter competing sides from exerting costly resources in early rounds of conflict.

Our experimental design considers the setting of symmetric players. While our framework captures some of the most salient features of the tug-of-war, we have set aside empirically relevant issues, such as contestant strength differences, heterogeneous prizes, and resource constraints. Given the observed deviations of behavior from theoretical predictions, exploring these extensions is an important avenue for future research.

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Appendix (For Online Publication) – Instructions for the *Low Value* Treatment

General Instructions

This is an experiment in the economics of decision making. Various research agencies have provided the funds for this research. The instructions are simple and if you follow them closely and make careful decisions, you can make an appreciable amount of money.

The experiment consists of **10** decision periods. The currency used in the experiments is called Francs. At the end of the experiment your earnings in Francs from **1** randomly selected period will be converted to US Dollars at the rate **25 Franks = US $1**. You are also being given a **US $20** participation payment. Any gains you make will be added to this amount, while any losses will be deducted from it. You will be paid privately in cash at the end of the experiment. The period that will be used to determine your payoff will be randomly selected at the end of the experiment using a 10-sided die.

It is very important that you do not communicate with others or look at their computer screens. If you have questions, or need assistance of any kind, please raise your hand and an experimenter will approach you. If you talk or make other noises during the experiment you will be asked to leave and you will not be paid.

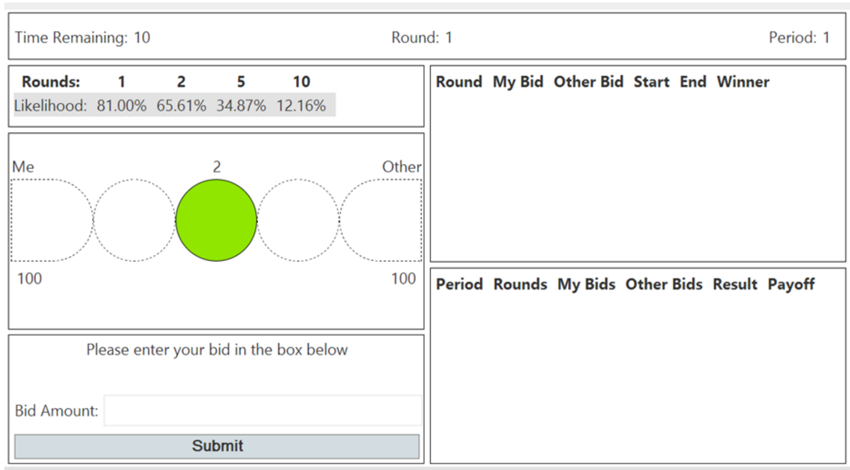
Instructions for the Experiment

Each period you will be randomly and anonymously paired with one of the other participants, but no participant will be able to identify if or when he or she has been paired with a specific person.

Every period you and the person that you are paired with for the period will have an opportunity to win a prize of **100 Franks**. The person who wins the prize is determined by a game of tug-of-war that occurs over the course of multiple *rounds*, so at most of one of you will win the prize in a period.

Each period lasts for a randomly determined number of *rounds*. The way the number of *rounds* is determined is as follows: after each round there is an **81%** chance that another *round* will occur. This means that there is a 19% chance that a period will end after a given *round*. Notice that the chance of the period continuing does not depend on how many *rounds* the period has already lasted. At any point in time, the probability of a period lasting at least N more *rounds* is 0.81^N. So the chance that a period will last for at least two more rounds is $0.81^2 = 65.61\%$. As you can see on the sample screen shot on the next page, by the heading "Rounds" your screen will show you the likelihood that the period will last at least 1, 2, 5, and 10 more *rounds*.

At the start of each period a green ball will be placed **2** spaces from you and **2** spaces from the participant with whom you have been randomly paired. Each *round*, you and the person you are paired with will make a bid. Any amount that you bid is instantly deducted from your payoff for the period. Bids cannot exceed the prize so bids can be anything from [0, 0.1, 0.2, …, 99.9, 100]. The ball will move **1** space closer to the person who bids the most that *round*. In the event of a tie, the ball will move towards the closer person. If the ball is equidistant from both of you then a tie will be broken randomly. This bidding process will continue until either 1) someone has moved the ball all the way to his side and thus claimed the prize of **100** or 2) the period ends due to the random process described above.



To place a bid you simply type it in the box on the lower left portion of your screen and press Submit. After both participants have placed their bids, each person will be informed of the bids and the outcome for that *round* in the upper right portion of their screen. The green ball will also be moved accordingly. The number above the green ball tells you how many more rounds you must win to claim the prize this period. This number is referred to as the *location*. The lower right portion of the screen will keep a record of what happened each period. Recall that at the end of the experiment, you will be paid based upon what happened in one randomly selected period.

Let’s look at a couple of examples:

1) Suppose that in Round 1 you bid 13 and the person you are paired with bid 45. Since the other person bid more, the ball would move one position to the right, away from you. If in Round 2 you bid 30 and the other person bid 10, the ball would move back to the left to its original position. At this point, it is as if the period just began except that you would have already spent 43 = 13+30 and the other person would have already spent 55 = 45+10.

2) Suppose that in Round 1 you bid 13 and the person you are paired with bid 45. Since the other person bid more, the ball would move one position to the right, away from you. If in Round 2 you both bid 18, the ball would move one more space to the right since there was a tie and the ball was closer to the other person. This would be the end of the period. The other person would claim the prize of 100 and earn a profit of 37 = 100–45–18. You would earn a profit of –31 = –13–18.

3) Suppose that in Round 1 you bid 65 and the person you re paired with bid 30. Since you bid more, the ball would move one position to the left, towards you. If by random chance the period ended after that round, your profit would be –65 and the other persons’ profit would be –30.

If you are finished reading these instructions, please raise your hand and an experimenter will bring you a review sheet to complete. The review sheet will not impact your payoff in any way; rather it is intended to ensure that you and everyone else understand the experiment.

Review Sheet

Please answer each of the following. If you have a question at any point, you should raise your hand and an experimenter will assist you.

1) Complete the following table by determining where the green ball would start and end each round given the bids listed.

Round	Starting Location	Your Bid	Other Person's Bid	Ending Location
1	2	15	26	3
2	3	18	13	
3		20	5	
4		38	39	
5		3	2	

2) Using the table above, what would your profit be if the period was randomly ended after the third round? ____________ What would the other person's profit be? _____________

3) Suppose instead that in round 1 you bid 10 and the other person bid 15. If both of you bid 0 in all subsequent rounds and the period was not randomly stopped before someone won the tug-of-war, what would your profit be? ____ What would the other person's profit be? _____

4) True of False, at the end of the experiment you will be paid the sum of your earnings each period.