Brothers in Arms - An Experiment on the Alliance Puzzle

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Abstract

The generic alliance game considers players in an alliance who fight against an external enemy. After victory, the alliance may break up, and its members may fight against each other over the spoils of the victory. Our experimental analysis of this game shows: In-group solidarity vanishes after the break-up of the alliance. Former 'brothers in arms' fight even more vigorously against each other than strangers do. Furthermore, this vigorous internal fighting is anticipated and reduces the ability of the alliance to mobilize the joint fighting effort, compared to a situation in which victorious alliance members share the spoils of victory equally and peacefully.

Keywords: Alliance, Conflict, Contest, Free-riding, Hold-up problem, In-group solidarity.

JEL classification code: D72, D74

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1 Introduction

Alliances are an important and widespread phenomenon in conflict. Psychologists emphasize the importance of fighting in an alliance. Baumeister and Leary (1995, p.499), for instance, argue that there is a "severe competitive disadvantage of the lone individual confronting a group" and that, "when other people are in groups, it is vital to belong to a group oneself". Other researchers emphasize the importance of group spirit; Campbell (1965, p.293) considers "the willingness to risk death for group causes" as one of the "things which makes lethal war possible". Work on alliances by Sherif et al. (1961) reveals the importance of the rival, or out-group, for the emergence of in-group solidarity and out-group hostility. Cohesion among brothers in arms is possibly generated by the common enemy or 'threat'.[1]

In contrast, narrow rational choice reasoning hints at two major disadvantages for the members of an alliance. First, in the competition between the alliance and its adversaries, the members of the alliance face a free-rider problem, as their contributions to the fighting effort in the inter-alliance competition are, to some extent, contributions to a public good (Olson and Zeckhauser 1966).[2] The members of an alliance - the 'brothers in arms' - all benefit from higher collective fighting effort of their alliance. However, each member should prefer additional effort to be expended by other members of his group. The members of an alliance also face a second strategic problem: if the alliance is victorious, they may quarrel over the division of the spoils of victory. The effort expended in this internal distributional conflict reduces the value they attribute to winning this prize. This should further discourage alliance members at the stage at which they decide upon their contribution

[1] See, e.g., Wilkins (2006) for a discussion of the 'realist' and the 'pluralist' theory in the context of the Normandy Campaign 1944.

[2] See, e.g., Baik, Kim and Na (2001), Baik, Hwan, and Lee (1998), Davis and Reilly (1999), Esteban and Ray (2001), Katz, Nitzan and Rosenberg (1990), Lee (1995), Nitzan (1991a), Nitzan (1991b), Nitzan (1994), Nitzan and Ueda (2008), Rapoport and Amaldoss (1997), and Ursprung (1990).

to the inter-alliance conflict.[3] These considerations may be summarized as the "alliance puzzle": on the one hand, to be in an alliance is vital on some accounts; but, on the other hand, alliances face strategic disadvantages that actually weaken the alliance members' position in the conflict, compared to stand-alone players.

Both psychological effects and rational choice considerations may be at work. Empirically, the formation and resolution of alliances is a dynamic phenomenon, and each cause of conflict is full of idiosyncrasies. This makes it difficult to distinguish between these effects and to measure their size empirically. The experimental laboratory, with its controlled environment, allows us to separate the different effects. International military alliances have many complex features, which lead to further relevant questions, ranging from the process of forming and dissolving alliances to the timing of alliance formation. These and many other aspects will, by intention, not play a role in the experimental framework; and, what seemingly is a weakness of the approach is in fact its main strength. Accounting for all these issues blurs the picture and generally causes considerable data problems. In the experiment, it is possible to remove the endogeneity problem and to detach a single conflict from the larger course of history, allowing us to concentrate on the strategic aspects that remain in our more narrowly defined framework.

We ask two main questions. First, we address the role of internal distributional conflict. Taking into account that future redistributional conflict within a victorious alliance reduces the value of winning, how important is the prospect of future redistributional conflict for the amount that alliance members contribute to the alliance effort? Does this future intra-alliance conflict among the members of a victorious alliance discourage its members from making effort contributions in the conflict between the alliance and its adversary, compared to a situation in which they must peacefully share the

[3] See Katz and Tokatlidu (1996), Esteban and Sákovics (2003), Müller and Wärneryd (2001), Wärneryd (1998), Konrad (2004).

spoils of victory? Second, we address the psychological effect of in-group and between-group dynamics. We ask: how do the alliance members' experiences of successfully fighting 'shoulder-to-shoulder' affect their willingness to turn against each other when they have to solve the distributional conflict between them? There is strong evidence showing in-group favoritism inside alliances, particularly if they are threatened by an enemy.[4] But does this mutual favoritism survive once the external enemy has been defeated, or does it disappear with the disappearance of the purpose that established the alliance?

In the experimental set-up, we study a contest between an alliance - consisting of two players - and a single player. Alliance players and the single player expend efforts trying to win a reward or prize of a given size. If the single player wins, he takes the prize and the game ends. If the alliance wins, the alliance players need to share this prize. We consider two different - exogenously imposed - regimes that differ in the rules concerning how the prize is allocated among the members of the alliance. In one regime, the alliance members must split the gains from winning evenly. In this regime, alliance players face only a free-riding problem. In a second regime, the members of an alliance that wins the prize have to fight about how to distribute the gains from winning between them. Here, in addition to the free-riding problem, alliance members face a hold-up problem: if they win, they enter into a costly internal fight. The comparison of these two regimes yields an answer to the first of the key questions: do brothers in arms behave differently in inter-alliance contest if future internal fighting among the members of a victorious alliance can be expected? The second key question compares contest efforts in two situations: (i) efforts of players who have been together in a winning alliance and now fight internally in the distribution conflict, and (ii) efforts of players who have not previously been together in an alliance, but fight in a two-player contest over a prize of the same size. This comparison provides insights about whether or not in-group solidarity, arising inside the alliance

[4]See, e.g., Bernhard et al. (2006), Brewer (1979), and Sherif et al. (1961).

during the process of fighting against an external enemy, survives the defeat of the enemy.

Our results are mostly in line with the rational choice theory of alliances, and we do not find strong evidence in support of the survival of in-group solidarity. First, compared to an alliance in which the spoils of victory are peacefully and evenly shared, alliance members contribute less to the total alliance effort if the members of a victorious alliance face a wasteful distributional conflict within the group. This behavior is in line with the predictions of the subgame-perfect equilibrium of players who care about their monetary payoff: alliance members who anticipate the strategic problem of intra-alliance fighting should expend less resources in the inter-alliance contest, because the dissipative internal conflict reduces the expected value of winning the inter-alliance contest. Second, we find no evidence that the experience of fighting 'shoulder-to-shoulder' in an alliance against a joint enemy reduces the alliance members' mutual hostility when it comes to dividing the spoils of victory. Despite the empirical findings about the formation of minimal groups and in-group favoritism within such groups in the presence of an out-group,[5] such in-group solidarity seemingly breaks down as soon as the joint enemy is defeated. If anything, former allies fight each other even more vigorously than contestants who have no joint history.

The different effects which we isolate and quantify in the laboratory can be illustrated by anecdotal evidence for wars. Apart from discussions of free-riding and strategies of burden shifting among allies[6], many writers emphasize a high potential for the break-up of the alliance when defeat of the enemy is imminent. The break-up of the Great Alliance right after the Second World War and the beginning of the Cold War is perhaps the best and most

[5]See Sherif et al. 1961; Charness et al. 2007; Chen and Li 2009; Sutter 2009; Ambrus et al. 2009.

[6]Starr (1972, p.28), for instance makes this point: "Indeed the Russians felt that the Western Allies had conspired to foist the human cost of the war upon them, as reflected in the delay in the opening of a second front, and the resulting casualty figures of the Red Army."

frequently cited example of former alliance members turning against each other and fighting over the spoils of war.[7] Similar anecdotal evidence is reported for the First World War (Bunselmeyer 1975) and for the Napoleonic War (O'Connor 1969). As Beilenson (1969, p.193) concludes: "Among victors, alliances have tended to dissolve at the peace table in quarrels over the spoils."

There is no experimental work of which we are aware that addresses the strategic effects of future conflict among current alliance members or the possible solidarity effect in the fight about dividing the spoils when having previously been 'brothers in arms'. However, structurally related questions have been addressed in the context of group contests. Ahn et al. (2011) compare group contests, individual contests, and individual-vs.-group contests and reject "the paradox of group size" proposed by Olson (1965). Sheremeta and Zhang (2010) consider contests between teams with intra-group communication and joint decision-making and compare them to individual contests. Sutter and Strassmair (2009) study how intra- and/or inter-group communication affect individually chosen effort levels in group contests. Abbink et al. (2010) study the effect of intra-group punishment on inter-group contests and find that allowing punishment greatly increases the dissipation rate. Gunnthorsdottir and Rapoport (2006) and Kugler et al. (2010) study the public goods problem embedded in group contests and focus on comparisons of the impact of two peaceful sharing rules (equal vs. proportional to efforts). In all these studies, the prize is either non-rival among group members or shared peacefully. These papers cover the problem of free-riding, but they do not address a possible conflict within the victorious group and its consequences

[7] An important warning can be found in the Records of the War Department General and Special Staffs, Plans and Operations Division, Exec. 8. Col. J. McNarney and Rear Adm. R.K. Turner, in the 'Joint Instructions for Army and Navy Representatives', Office of the Chief of Staff, Washington DC, 21 January 1941, in preparation of the Allied conferences: "Never absent from British minds are their postwar interests, commercial and military. We should likewise safeguard our eventual interests." (Cited in Wilkins 2006, p.1136.)

for the inter-alliance conflict. Also, the existing studies do not address our key question of whether former 'brothers in arms' fight less violently with each other than strangers do.

Another important line of experimental research considers contests more generally. Most of the studies focus on one-stage contests (e.g., Millner and Pratt 1989; 1991; Shogren and Baik 1991; Davis and Reily 1998; Potters et al. 1998; Anderson and Stafford 2003), and few on multi-stage contests (Schmitt et al. 2004; Parco et al. 2005; Sheremeta 2010). As a common result, individuals expend more effort than would be predicted in equilibrium. Explanations of over-dissipation include non-monetary utility of winning (Parco et al. 2005; Sheremeta 2010), misperception of the winning probabilities (Baharad and Nitzan 2008), quantal response equilibrium and heterogeneous risk preferences (Goeree et al. 2002, Sheremeta 2011). These papers address neither the role of future conflict among players at the stage in which they are 'brothers in arms' nor whether their joint history moderates internal fighting.

2 Theoretical setup

We consider two contest games with complete information. There are three players A, B, and C who compete for a given prize of value V. Each player chooses a non-negative amount of effort, denoted x_A, x_B, and x_C, respectively. Players A and B are in an alliance denoted AB and compete with player C. The following contest success function describes how players' efforts translate into win probabilities of the alliance and of player C. The probability that the alliance AB wins this contest is equal to

$$p_{AB} = \begin{cases} \frac{x_A+x_B}{x_A+x_B+x_C}, & \text{for } x_A+x_B+x_C>0 \\ \frac{1}{2}, & \text{for } x_A+x_B+x_C=0 \end{cases}, \tag{1}$$

and the probability that player C wins is equal to the remaining probability $p_C = 1 - p_{AB}$. This contest success function describes what is commonly known as the Tullock lottery contest.[8] Costs of efforts are equal to a player i's effort x_i, $i \in \{A, B, C\}$.

If player C wins, he gets the prize. If the alliance AB wins, the prize has to be allocated among players A and B. We consider two exogenously given allocation rules: the equal-sharing rule and the contest rule. If the equal-sharing rule applies, players A and B each get one half of the prize, disregarding the efforts that players A and B expended in the contest with player C. If the contest rule applies, players A and B must compete for the prize. They have to expend effort y_A and y_B, respectively, in an intra-alliance contest between them.

The expected monetary payoff of each player, $E\pi_i$, is given as:

$$E\pi_i = p_{AB}v_i - x_i \text{ if } i \in \{A, B\} \tag{2}$$

$$E\pi_C = p_C v_C - x_C \tag{3}$$

where v_i denotes the valuation which player $i \in \{A, B\}$ attributes to the outcome in which the alliance wins the prize. In the regime with equal sharing, v_i is simply equal to $V/2$. In the regime with internal fighting, v_i also depends on the choices of fighting efforts in the internal contest and the allocation rule that maps these efforts into win probabilities, as will be discussed further below. If player C wins, he gets the entire prize, thus $v_C = V$.

Case 1: Equal sharing If players A and B must split the prize equally, in the case of them winning against C, then $v_A = v_B = V/2$. If the alliance players choose their effort non-cooperatively and each player maximizes his

[8] This function has been invented and used independently to describe contests in different fields and has also received multiple axiomatic foundations. See, e.g., Konrad (2009, pp. 42-53) for a detailed survey.

expected monetary payoff as given in (2) and (3), respectively, the resulting equilibrium efforts are

$$(x_A + x_B)^* = \frac{V}{9} \text{ and } x_C^* = \frac{2V}{9}. \tag{4}$$

The sum of efforts $(x_A + x_B)^*$ in (4) is smaller than player C's equilibrium effort x_C^*, and, for A and B, only the sum $(x_A + x_B)^*$ is uniquely determined in equilibrium. These two properties can be explained by a comparison of the marginal conditions that characterize the equilibrium. For given $(x_A + x_B)^*$, player C contributes x_C that fulfills the marginal condition $(-\partial p_{AB}/\partial x_C) V = 1$, and for given x_C^*, the marginal condition that determines the contributions of both players A and B is given by

$$\frac{\partial p_{AB}}{\partial (x_A + x_B)} \frac{V}{2} = 1. \tag{5}$$

This condition (5) takes into account that x_A and x_B are chosen simultaneously and independently and that, in an interior equilibrium, each player A and B must be indifferent about whether to increase $(x_A + x_B)$ by a marginal unit. A comparison of the marginal conditions reveals that $x_C^* > (x_A + x_B)^*$. Also, (5) determines the total contribution $(x_A + x_B)^*$, but not how this sum is composed of x_A and x_B; if $(x_A + x_B)^*$ makes (5) hold, then (5) holds for any (x_A, x_B) with $x_A + x_B = (x_A + x_B)^*$.[9] Expected equilibrium payoffs are

$$(E\pi_A + E\pi_B)^* = \frac{2V}{9} \text{ and } (E\pi_C)^* = \frac{4V}{9} \tag{6}$$

where, again, only the sum of players A and B's payoff is uniquely determined. The alliance's joint payoff is smaller than the payoff of the single player.[10]

[9] See Nitzan (1991a) for a more formal proof.

[10] This holds qualitatively, even if, for whatever reason, the players A and B could choose their efforts cooperatively in the contest against player C, due to prize sharing.

Case 2: Internal fight Suppose that, if the alliance wins the prize, the alliance members must allocate the prize as the outcome of an internal fight. Let this intra-alliance contest follow, again, the rules of the lottery contest. Recall that A's and B's efforts in this intra-alliance fight are non-negative and denoted by y_A and y_B. A's probability of winning this intra-alliance contest is

$$q_A = \begin{cases} \frac{y_A}{y_A+y_B}, & \text{for } y_A + y_B > 0 \\ \frac{1}{2}, & \text{for } y_A + y_B = 0 \end{cases}, \tag{7}$$

and B's winning probability is $q_B = 1 - q_A$. If player $i \in \{A, B\}$ wins this internal fight, he obtains the entire prize V. Both players, however, have to pay their cost of effort, y_A and y_B, respectively. Conditional on reaching this subgame, player $i \in \{A, B\}$ has an expected continuation payoff $q_i V - y_i$. The Nash equilibrium efforts in this subgame are

$$y_A^* = y_B^* = \frac{V}{4}. \tag{8}$$

Thus, player $i \in \{A, B\}$ obtains an expected continuation payoff (net of effort cost y_i) in this subgame equal to

$$q_i V - y_i = \frac{V}{2} - \frac{V}{4} = \frac{V}{4} \text{ for } i \in \{A, B\}.$$

Hence, an alliance player's expected valuation (net of effort cost) of winning against C is equal to $V/4$ (i.e., $v_A = v_B = V/4$). This valuation is only half of the valuation of winning in the regime where A and B share the prize peacefully. Consequently, the alliance players' efforts x_A and x_B in the contest against C are lower in the regime with internal fighting. Straightforward calculations yield

$$(x_A + x_B)^* = \frac{V}{25} \text{ and } x_C^* = \frac{4V}{25}. \tag{9}$$

In total, expected payoffs are equal to

$$(E\pi_A + E\pi_B)^* = \frac{3V}{50} \text{ and } (E\pi_C)^* = \frac{16V}{25}. \tag{10}$$

In this regime, the difference between expected payoffs of alliance players and the single player is even larger: potential internal fight about the prize is a second important disadvantage of fighting in an alliance.

3 The experiment

Our experiment is composed of three treatments that measure the effects of internal conflict, on the one hand, and test for the importance of a joint fighting experience on the other hand. In the base (*Share)* treatment, two alliance players (A and B) are teamed up exogenously and fight against a player C for a prize of 450. Players A, B, and C independently choose their efforts x_A, x_B, and x_C from the set $\{0, 1, 2, ..., 250\}$. Then, the three choices (x_A, x_B, and x_C) within one group are displayed, and the lottery contest success function given in (1) determines whether the alliance AB or the sole player C wins. The probabilistic nature of the outcome of the lottery contest is illustrated graphically by a dynamic fortune wheel.[11] Having followed the outcome of the fortune wheel, subjects are given their profits for the period. If the alliance wins, each of the alliance members gets half of the prize; if the sole player wins, he/she receives the full prize.

A second treatment, called *Fight,* is identical to treatment *Share*, except that, if the alliance players win the contest against player C, they have to enter into an intra-alliance contest to determine who gets the full prize. Hence, if the alliance of players A and B wins the prize, then the game

[11] It is a well-known problem that it is difficult for the subjects to understand the probabilities as they emerge from the contest success function. In the fortune wheel, the efforts are translated into colored segments that correspond to the share of $x_A + x_B$ and x_C, respectively, in total effort $x_A + x_B + x_C$. The segment in which the arrow stops determines whether the alliance AB or player C wins the contest.

Treatment	Share	Fight	FightNH
Prize	450	450	450
Players	AB⇔C	AB⇔C	A⇔B
Prize sharing (between A and B)	50, 50	Contest	Contest
$(x_A + x_B)^*$, x_C^*	(50, 100)	(18, 72)	–
y_A^*, y_B^*	–	(112.5, 112.5)	(112.5, 112.5)
$(E\pi_A+E\pi_B)^*, (E\pi_C)^*$	(100, 200)	(27, 288)	–
$(E\pi_A)^*, (E\pi_B)^*$	–	–	(112.5, 112.5)

Table 1: Treatment specifications.

continues. Players A and B have to simultaneously choose their intra-alliance contest efforts y_A and y_B. Again, after choices have been made, these efforts y_A and y_B are shown on the screen, and another fortune wheel determines the winner between the two. The winner in the lottery contest between A and B receives the full prize. A comparison of treatments *Share* and *Fight* will shed light on how the effort choices of alliance players in the inter-alliance contest are influenced by the intra-alliance prize sharing rule.

The third treatment *FightNH* (NH stands for “no history”) is conducted to elaborate on whether former ‘brothers in arms’ fight differently in the intra-alliance contest than two strangers do in the same contest. In the *FightNH* treatment, there are only two players, A and B, who play the lottery contest for a prize of 450 and who had no former history of inter-alliance competition.

Table 1 gives an overview of the three treatments. Columns 2-4 describe the features of these treatments and survey the effort levels and expected payoffs in the subgame-perfect equilibrium for players who maximize their material payoffs.

The experiment was programmed using z-Tree (Fischbacher 2007) and run in MELESSA, the Munich Experimental Laboratory for Economic and Social Sciences, in 2011. Each experimental session involved 24 studentsubjects playing one out of the three treatments.[12] The data was collected from three sessions each for treatments *Share* and *Fight*, and from one session for treatment *FightNH*. Overall, 165 subjects participated in the experiment; they were students from all fields of study.[13] Each subject played only one treatment and had a fixed role (either player A or B, or player C) in this treatment. This role (as A, B, or C) was randomly assigned by the computer program. The instructions of the respective treatment were read out aloud to all players. Each treatment consisted of 30 rounds, and subjects kept their assigned roles throughout these rounds. However, subjects were randomly rematched in each round within their session group in order to avoid repeated interaction behavior.

Subjects were given written instructions at the beginning of each session (see Appendix for a sample). To ensure that they properly understood the instructions, they had to answer a set of pre-experiment questions. The experiment only started after the subjects had correctly answered the testing questions. At the end of the experiment, the subjects had to fill in a questionnaire that collected some basic information such as individual characteristics. Afterwards, they were paid separately and in private. Subjects received a EUR 4 show-up fee. In addition, they were paid EUR 0.6 for each round played, which essentially served as their endowment in the contest. Profits from 6 rounds (out of 30) were randomly drawn to be added to (or deducted from, if negative) the payment per round. On average, the subjects earned EUR 30, and a session took about 1.5 hours in total.[14]

[12] In one of the sessions of the *Share* treatment, the number of participants was only 21.

[13] The participants were recruited using the software ORSEE (Greiner 2004).

[14] The final payment varied substantially for different subjects (ranging from EUR 8 to EUR 70), which assured that our design induced sufficient monetary incentives for subjects to make careful decisions.

4 Hypotheses and main results

The main questions that motivate our analysis are: (1) Does the nature of the subgame in which alliance members solve the problem of distributing the prize among themselves affect their contributions to the total effort of the alliance? (2) Does the experience of having been 'brothers in arms' in the contest against an outsider change alliance members' fighting if the division of the prize among them follows the rules of a contest? In particular, does a possible in-group solidarity effect carry over to the contest between former 'brothers in arms'? These questions and the related theory considerations translate into two main hypotheses.

Hypothesis 1: *In the contest between the alliance and the out-group player, average effort of alliance players is higher if the members of a victorious alliance share the prize equally than if they fight among themselves about the prize.*

Note that this hypothesis follows straightforwardly from economic theory (Katz and Tokadlidu 1996, Esteban and Sákovics 2003): future conflict about the prize reduces the value of winning this prize. This makes it less attractive for the alliance group to win, and this should reduce their joint efforts. Note also that this effect should emerge whether the alliance members' contributions are determined by non-cooperative behavior or by group-spirited considerations.

The second hypothesis concerns the role that a 'brothers in arms' experience plays in determining the intensity of fighting between the members of a victorious alliance over who eventually receives the prize. In order to see whether the former in-group experience matters, we compare the effort of former 'brothers in arms' with the effort of complete strangers in a situation that otherwise is the same lottery contest for the same prize value. We formulate two mutually incompatible hypotheses:

Hypothesis 2a: *Former brothers in arms expend the same effort in the* *internal conflict as do players without a common history.*

From a theory perspective, this hypothesis describes equilibrium behavior in the subgame in stage 2 for players who care about material reward only. The anecdotal evidence of the break-ups of war alliances at the end of war and the intensity of the Cold War may lend empirical support to the rational choice prediction summarized in Hypothesis 2a. The competing hypothesis is:

Hypothesis 2b: *Former brothers in arms expend less effort in the internal conflict than do players without a common history.*

This hypothesis is based on considerations and empirical results in several social science disciplines. Players who share a group identity and who took part in a joint initiative and succeeded may show a behavior that may, but need not, exhibit different patterns of interaction than an interaction among strangers, even in an identical strategic context. In experimental group contests, intra-group communication, for instance, can strengthen group identification and result in higher group efforts (Cason et al. 2012). Moreover, in repeated public goods games, partner matching induces higher contributions but also shows a very strong end-game effect.[15] Players in a trust game who are recruited from the same (laboratory induced) group show slightly more trust than in the absence of this group identity effect (Smith 2011). There is also evidence that people show gratitude towards their benefactors if they benefited from "costly, intentional, voluntary effort on their behalf" (McCullough et al. 2008, p.281). In our context, the winners in an alliance are players who may have developed some group identity when fighting jointly in an alliance and who experienced joint success as a result of their effort

[15] The influential paper by Keser and van Winden (2000) shows that partners manage to sustain more collaboration than strangers. The effect is considerably reduced in later rounds and almost vanishes in the last round. Sonnemans et al. (2006) also consider multi-rounds public goods games with partner matching, developing a theory of the formation of social ties that are partially based on experience in previous rounds. Building on insights from sociology, they conjecture that "...social ties will develop during a repeated public good game [...] and that these ties will depend on the payoff of the interaction" (p.189).

Average Rate of Dissipation (effort / total prize value)						
Treatment	Prediction		Round 1-15		Round 16-30	
	A+B	C	A+B	C	A+B	C
Share	0.11	0.22	0.23	0.32	0.17	0.32
Fight(stage1)	0.04	0.16	0.21	0.30	0.12	0.28
Fight(stage2)	0.50		0.72		0.86	
FightNH	0.50		0.70		0.70	

Table 2: Average dissipation rate by treatment.

choices. This may generate trust, gratitude and the expectation of other types of pro-social behavior on the part of their former comrade and therefore may lead to accommodating behavior as regards own fighting effort and hence to less intense fighting.

Before turning to the assessment of these main hypotheses, it is reassuring to note that the individuals in the experiment exhibit certain behavioral regularities that are known from other contest experiments. Typically, individuals in lottery contests expend more effort than would be desirable for individuals wishing to maximize their monetary payoffs; individuals in our experiment also show this pattern. Table 2 provides the dissipation rates (defined as the total effort expended by players A and B and by player C, respectively, divided by the prize value) observed in the experiment, compared to their theoretical predictions, for all treatments.

In all treatments, the observed dissipation rate is higher than the predicted dissipation rate, both for alliance players and for single players. In the *Share* treatment (where alliance players receive equal shares of the prize in case of a victory), theory predicts a dissipation rate of 11% and 22% for alliance players and for single players, respectively. The observed dissipation rate is 17% for alliance players and 32% for single players (in rounds 16-30); hence, while all players choose higher effort than predicted, the observed ratio of the alliance's joint effort to player C's effort in later rounds is close to the theory prediction of 0.5.[16] Overall, subjects in the *Share* treatment dissipate 49% of the prize value (in rounds 16-30), compared to the equilibrium prediction of only 33%.

In the *Fight* treatment, the dissipation rate in the inter-alliance contest should be lower than in *Share* since alliance players will face a second-stage contest if they win. Indeed, the dissipation rate in stage 1 in *Fight* is reduced to 12% for the alliance (in rounds 16-30), but it is still higher than the theory prediction of only 4%. Similarly, single players reduce their effort in *Fight* and dissipate 28% of the prize (in rounds 16-30), compared to the prediction of 16%. In contrast to *Share*, overdissipation is more pronounced for alliance players: The observed ratio of joint alliance effort to player C's effort is 0.43 and, therefore, higher than the theory prediction of an effort ratio of 0.25.[17]

Moreover, the dissipation rate in stage 2 of the *Fight* treatment is higher than theoretically predicted (86% compared to the prediction of 50%), and it goes up in later periods (compare the last two columns in Table 2). Finally, in the *FightNH* treatment, which is a symmetric two-player contest, the dissipation rate is 70% and, hence, again higher than the theoretically predicted 50%. This generally higher-than-predicted effort is a common phenomenon in contests and has been explained by factors like an intrinsic utility of winning or a misperception of the winning probabilities, among others.

Hypothesis 1 Let us now turn to the first main hypothesis on effort choices in the inter-alliance conflict, starting with a descriptive analysis. Figure 1 plots average individual effort in stage 1 for the treatments *Fight* and *Share*, separating alliance players and single players. Average effort of an alliance player (A or B) is much lower than a single player's average effort. This is in line with their lower monetary incentives to win the inter-alliance con-

[16] This confirms that, as theoretically predicted, there is substantial free-riding among alliance members.

[17] Accordingly, although the ratio of alliance's joint effort to player C's effort is lower in *Fight* (0.43) than in *Share* (0.53), the hold-up effect of the internal fight on the this ratio is weaker than what is predicted by theory.

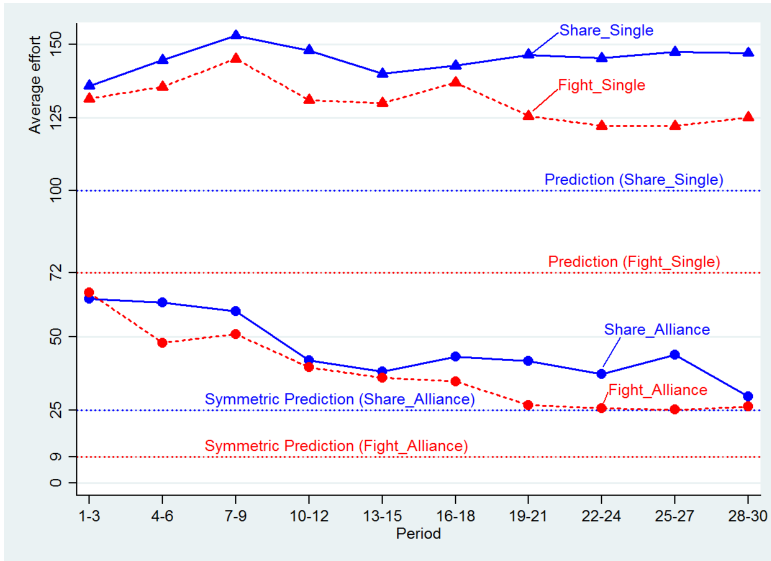

Figure 1: Average effort for alliance and single players by treatment.

test. Both alliance players and single players expend less effort in the *Fight* treatment than in the *Share* treatment, in line with the theory prediction. Anticipation of the subsequent internal conflict in the *Fight* treatment seemingly causes alliance players to reduce their effort in stage 1; in turn, the lower effort of single players in *Fight,* compared to *Share,* might constitute a reaction to the reduced alliance effort. While single players' efforts are rather stable over time, experience is important for alliance players (who adjust their effort choices toward the theory prediction). The fact that learning is more important for alliance players is not surprising, given the more complex incentives they face.

To quantitatively confirm the effect of the intra-alliance contest on effort in the inter-alliance contest, we estimate effort choices in stage 1 in random-effects Tobit models[18] where the estimated equation is

$$
\begin{aligned}
x_{it} &= \beta_0 + \beta_1 \times \mathit{FIGHT} + \beta_2 * t(1..15) + \beta_3 \times \mathit{FIGHT} \times t(1..15) \\
&\quad + \boldsymbol{\gamma} \times \mathbf{z} + \mu_i + \varepsilon_{it}.
\end{aligned}
$$

All estimations include a treatment dummy for the *Fight* treatment (FIGHT), a dummy variable indicating whether or not the observation stems from the first half of the experiment ($t\,(1..15)$), and an interaction of FIGHT and $t\,(1..15)$, to capture both treatment and learning effects. Hence, the constant β_0 measures average effort in the *Share* treatment in rounds 16-30.[19]

Moreover, some estimations also include individual characteristics obtained from the exit questionnaire as additional control variables, summarized in the vector $\mathbf{z}$. Besides gender, age, height and number of siblings ("NoOfSiblings"), we also include a dummy variable "Economist" indicating whether the participant studies economics or business administration (as a major or minor subject) and individual risk attitudes ("RiskTaking"). The latter variable is generated by asking the participants in the exit questionnaire to indicate their willingness to take risks, in general, on a scale from 0 to 10.[20] We estimate the effort choice of alliance players and single players separately; Table 3 shows the regression results of the random-effects Tobit models for the two subsamples. Among all individual characteristics, only those variables are reported that significantly explain individual effort choices.

Consider, first, alliance players' choices. Estimation (1) in Table 3 includes only the treatment dummy FIGHT and the dummy for the first half

[18]There are a significant number of choices at the boundary of the interval of possible choices (compare also Figure 2).

[19]We use data from periods 16 to 30 (instead of periods 1 to 15) as the base category because our focus in the analysis is on the treatment difference when subjects are rather familar with the tasks after sufficient periods of learning.

[20]Dohmen et al. (2011) compare the answer to this question with behavior in lottery choice problems. Their results suggest that the question is a simple and valid measure of risk attitudes.

Data set:	**Alliance players**		**Single players**	
Dependent var.:	effort x_A or x_B		effort x_C	
Model:	(1)	(2)	(3)	(4)
Constant	34.48***	31.65***	152.39***	150.82***
	(5.33)	(7.07)	(15.34)	(16.68)
FIGHT	-20.25***	-22.61***	-20.46	-37.39*
	(7.49)	(7.17)	(21.48)	(19.19)
t(1..15)	15.66***	15.66***	-2.55	-2.56
	(2.34)	(2.34)	(3.98)	(3.98)
FIGHT×t(1..15)	11.51***	11.48***	12.05**	12.05**
	(3.33)	(3.33)	(5.57)	(5.57)
Individ. characteristics	No	Yes	No	Yes
RiskTaking		4.51***		16.17***
		(1.68)		(4.46)
NoOfSiblings		5.37*		-16.58*
		(3.08)		(8.66)
Economist		5.12		100.51***
		(8.43)		(29.29)
Log likelihood	-12492.99	-12486.61	-6699.51	-6691.13
Wald χ^2	178.70***	192.19***	6.81*	27.21***

Note: There are 2820 observations in regression 1 and 2 (487 left-censored obs., 2325 uncens. obs., 8 right-cens. obs.) and 1410 obs. in regression 3 and 4 (22 left-cens. obs., 1204 uncens. obs., 184 right cens. obs). Standard errors in parentheses. ***(**, *) p-value<0.01(0.05, 0.1). Observations in the "Share" treatment from periods 16-30 taken as the baseline group. FIGHT and t(1..15) are dummies indicating whether the observation is from the "Fight" treatment and from periods 1-15, respectively.

Table 3: Random-effects Tobit models on effort in the stage 1 contest.

of the experiment ($t(1..15)$). Estimated average effort of an alliance player in the *Share* treatment and rounds 16-30 is equal to 34.48 (compare the constant), and there is an estimated treatment effect of the *Fight* treatment of about -20.[21] Focusing on rounds 16-30, we can reject (at the 1%-level) that efforts in the *Share* and the *Fight* treatments are the same. In rounds 1-15, however, we do not find a significant treatment effect for the *Fight* treatment: FIGHT+FIGHT$\times t(1..15)$ is not significantly different from zero. Thus, learning seems to be important for alliance players in understanding that future dissipation of the prize should make them reduce their stage 1 effort. Including individual characteristics as additional control variables (estimation (2)) does not affect the size and significance levels of the treatment effects.[22]

The treatment effects of FIGHT for single players are similar to those for alliance players, but much weaker: Effort choices in the *Fight* treatment are lower than in the *Share* treatment; however, this effect is only weakly significant (p-value is 0.051) when including individual-specific characteristics (compare estimations (3) and (4) in Table 3). Moreover, the treatment effect again disappears when focusing on the first half of the experiment; as for alliance players, FIGHT+FIGHT$\times t(1..15)$ is not significantly different from zero. In summary, single players react to the diminishing joint alliance effort by slowly reducing their own effort, and weak evidence on treatment differences only emerges in the second half of the experiment.

The coefficients for the individual-specific control variables show that participants who claim to be more willing to take risks choose significantly higher effort (estimations (2) and (4) in Table 3).[23] The number of siblings has a

[21] These estimated coefficients take into account the non-negativity of effort choices and are therefore slightly lower than average effort choices in the two treatments as shown in Figure 1 and computed in Table 2. A similar comment applies to the estimated coefficients in Table 4 where the observations are mainly bounded from above and the estimated coefficients are therefore higher than average effort as shown in Figure 3.

[22] Moreover, the result is robust to additional control on the dependence at the session level, using multilevel mixed-effects estimations.

[23] Since the "RiskTaking" variable has been generated in the exit questionnaire, we are

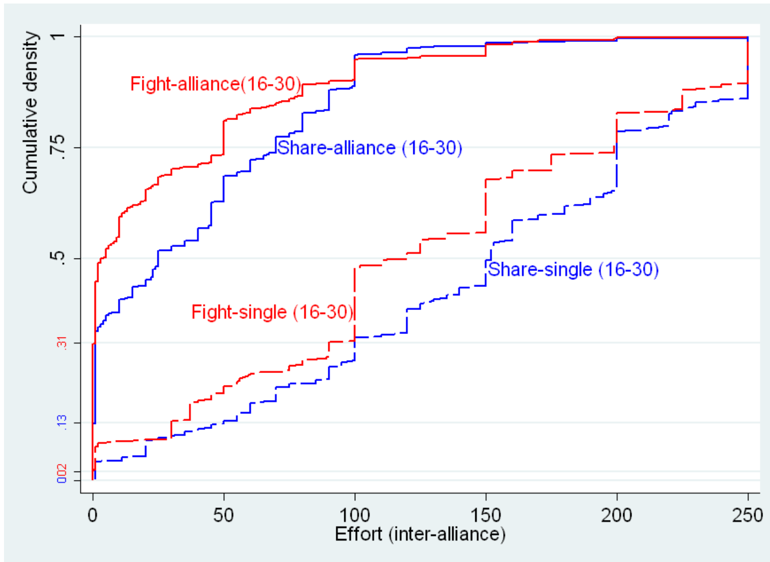

Figure 2: Distribution functions of stage 1 effort (rounds16-30).

weak but ambiguous effect: Having more siblings tends to increase alliance players' efforts but decreases single players' efforts.[24] Finally, for single players, economics students choose higher effort.[25]

Result 1 *In anticipation of internal conflict over the spoils of victory, alliance members significantly reduce their effort in the conflict with the single player, compared to a situation where victorious alliance members split the prize peacefully.*

The estimation results show that future dissipation of the prize indeed leads to a hold-up problem and significantly reduces efforts in the inter-

not trying to claim any causality here, but mainly use this variable as control variable. The main treatment effect is also robust in the estimations without this additional control variable.

[24] A possible interpretation is that players who have siblings show stronger in-group solidarity, but we would rather take it simply as a control variable and not speculate, since this question is not within the focus of our analysis.

[25] The overall share of economics students in the sample is about 20%.

alliance contest as well as the alliance's success. This finding is confirmed when plotting the cumulative distribution functions of individual effort choices from periods 16 through 30 (see Figure 2). Figure 2 reveals that individual effort choices exhibit a large variation (which is consistent with previous contest experiments), but it also shows that for both alliance and individual players, low efforts occur more frequently in the *Fight* treatment than in the *Share* treatment. In particular, in the *Fight* treatment, there is a much larger share of alliance players who expend very low effort in the inter-alliance contest. Hence, anticipated future internal fighting shifts both the alliance players' and the single player's effort choice distributions to the left.[26]

Hypotheses 2a and 2b We now turn to the internal fight between former 'brothers in arms' and examine whether alliance players fight more or less fiercely against each other than strangers who have no common history. We compare the effort choice in the second stage of the *Fight* treatment to the effort choices in the simple two-player Tullock contest without history (in *FightNH* treatment).

Figure 3 illustrates average effort choices in both treatments. While at the beginning of the experiment average effort choices in *Fight* and *FightNH* are very similar, they increase over time in the *Fight* treatment[27] and re-

[26]In addition to the effect of future prize dissipation, alliance players face the free-riding problem (both in *Share* and in *Fight*) when contributing to joint alliance effort. In the exit questionnaire, we also asked alliance players: "In the competition with player C, have you tried to expend less effort than your co-player within the alliance in order to benefit from his effort?" The share of participants who agreed to this question is higher in the *Fight* treatment than in the *Share* treatment (52% compared to 39%), although not significantly different (the p-value of a two-sample t test is 0.169). The participants' answers are strongly correlated with their average effort choice: the Spearman correlation coefficient of individual average effort in periods 16-30 and agreement to the question on free-riding is -0.418 (p-value is 0.004) for the *Share* treatment and -0.383 (p-value is 0.007) for the *Fight* treatment.

[27]Note that, in the *Fight* treatment, stage 1 and stage 2 efforts exhibit an opposite trend (compare Figures 1 and 3): while alliance players' stage 1 efforts decline, their stage 2 efforts rise over time. But, overdissipation rates (here defined as the ratio of observed effort and theoretically predicted effort) in stages 1 and 2 are converging: in early

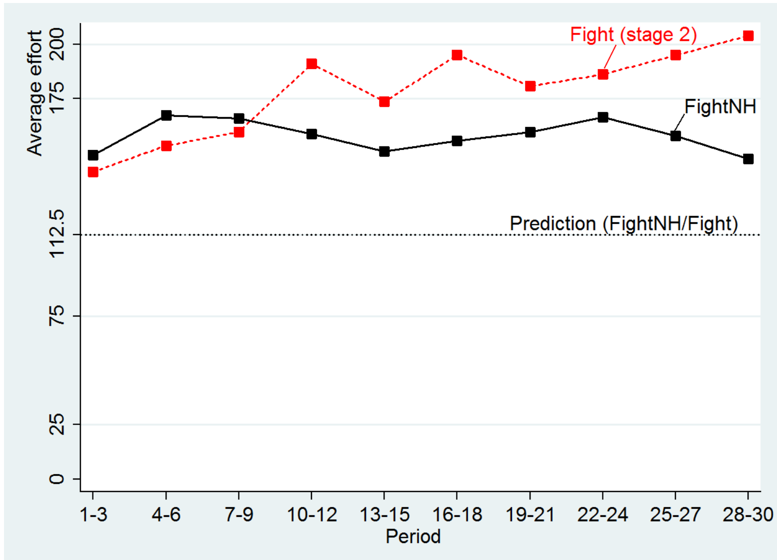

Figure 3: Average effort in two-player contests (*Fight* vs. *FightNH*)

main rather constant in the *FightNH* treatment. Hence, contrary to what a 'brothers-in-arms' effect would have induced, in-group solidarity may exist during stage 1, when the players fight jointly in an alliance, but it seemingly does not survive the break-up of the alliance. Rather, efforts in the intra-alliance contest appear to be even higher than in the contest in which the players do not have a joint history.

As before, we estimate individual effort in the two-player contest as a function of a treatment dummy FIGHT, a dummy for the first half of the experiment ($t\,(1..15)$), and additional control variables. Besides individual characteristics, we also control for effort choices in stage 1 of the *Fight* treat-

periods, overdissipation is more pronounced in stage 1 than in stage 2, compared to late periods. Similar results for such opposite trends in multi-stage contests have been found by Sheremeta (2010). An explanation for such behavior (also proposed by Sheremeta 2010) is that, in the complex structure of a two-stage contest, individuals will employ simple heuristics in early rounds that cause efforts in the two stages to be not "too different". When gaining more experience, however, individuals correctly reduce their stage 1 effort and increase effort in stage 2.

ment to examine whether they have an impact on the behavior in stage 2. Table 4 summarizes the results of several random-effects Tobit estimations; the baseline category is the *FightNH* treatment.

In estimation (1), without additional control variables, estimated average effort in the second half of the *FightNH* treatment is equal to 170.41 (compare the constant); the estimation for the *Fight* treatment, however, is 41.61 points higher. In contrast to both Hypothesis 2a and Hypothesis 2b, there is a significant treatment effect of the *Fight* treatment, leading to *higher* effort choices in the contest in which the players have a joint history. Again, this treatment effect is only significantly different from zero in the second half of the experiment, and there is no treatment effect in rounds 1-15 (FIGHT+FIGHT$\times t$ (1..15) is close to zero). Adding individual-specific control variables in estimation (2) weakens the treatment effect somewhat, though the effect of having a joint history remains weakly significant. Among the individual characteristics, only the willingness to take risks significantly explains effort choices, and, as for the inter-alliance contest, participants who describe themselves as generally more willing to take risks expend more effort. Estimation (3) adds several variables from the inter-alliance conflict to test whether having expended more/less-than-average effort in stage 1 of the *Fight* treatment (variable $x_{it} - \bar{x}_t^{A,B}$) explains stage 2 effort; in addition, the co-player's stage 1 effort compared to average stage 1 effort is included (variable $x_{-it} - \bar{x}_t^{A,B}$). None of these variables capturing the specific history of effort choices in the *Fight* treatment are significant, and their inclusion does not significantly change the treatment effect for the *Fight* treatment.[28]

Summarizing, we can reject Hypothesis 2a as well as Hypothesis 2b. Neither are effort choices independent of the history (as would be predicted by equilibrium play among monetary payoff maximizing players), nor does the joint history lead to an in-group solidarity effect that survives the break-up

[28] Again, this result is also robust in multilevel mixed-effects estimations that control for dependence of observations at the session level.

Dependent Variable:	Effort y_A or y_B		
Model:	(1)	(2)	(3)
Constant	170.41***	182.78***	182.13***
	(16.58)	(19.28)	(19.49)
FIGHT	41.61**	36.78*	39.07*
	(20.78)	(20.77)	(21.17)
t(1..15)	-0.09	-0.08	-0.08
	(4.92)	(4.92)	(4.91)
FIGHT×t(1..15)	-38.65***	-38.73***	-37.64***
	(8.01)	(8.01)	(8.71)
Individual characteristics	No	Yes	Yes
RiskTaking		8.17*	8.79*
		(4.75)	(4.81)
$(x_{it} - \bar{x}_t^{A,B})$×FIGHT			-0.15
			(0.11)
$(x_{it} - \bar{x}_t^{A,B})$×FIGHT×t(1..15)			-0.13
			(0.14)
$(x_{-it} - \bar{x}_t^{A,B})$×FIGHT			-0.08
			(0.10)
$(x_{-it} - \bar{x}_t^{A,B})$×FIGHT×t(1..15)			-0.05
			(0.13)
Log likelihood	-5394.65	-5392.24	-5387.41
Wald(χ^2)	38.31***	43.23***	52.53***

Note: There are 1246 observations in total (20 left-censored obs., 910 uncens. obs., 316 right-cens. obs.). Standard errors in parentheses. ***(**, *) p-value<0.01(0.05, 0.1). Observations in the "FightNH" treatment from periods 16-30 taken as the baseline group. FIGHT and t(1..15) are dummies indicating whether the observation is from the "Fight" treatment and from periods 1-15, respectively. x_{it} and x_{-it} are own and alliance partner's stage 1 effort in period t (in the "Fight" treatment); $\bar{x}_t^{A,B}$ is the average alliance stage 1 effort in period t.

Table 4: Random-effects Tobit models on effort in the two-player contest.

of the alliance and keeps efforts in the intra-alliance conflict low. Consistent with previous group contest experiments which find that the existence of competition with an out-group enhances in-group coordination (e.g., Bornstein et al. 2002), alliance players' efforts in the joint fight against the single player are initially much higher than would be predicted in theory in both the *Share* and *Fight* treatments. This in-group solidarity even turns into greater hostility after the break-up of the alliance.

Result 2 *Former partners of a victorious alliance expend significantly more effort in the conflict about the spoils of victory than players without a common history as alliance partners.*

Assessing this result, several potentially countervailing effects might have caused different behavior in the intra-alliance contest of the *Fight* treatment compared to a standard two-player contest, as in the *FightNH* treatment. In particular, the result of higher efforts in the *Fight* treatment could potentially be caused by two factors that might raise effort levels in the second stage of the contest: a selection bias and the sunk cost problem. It is important to control for these effects, as they could potentially cloud a possible solidarity effect.

First, in the *Fight* treatment, the subsample of participants reaching stage 2 might not be drawn from the same distribution as the sample of observations in the *FightNH* treatment. Rather, there could be a selection of subjects in the Fight treatment who, for some reason, spent more effort in stage 1 and in this way made the alliance win. If those subjects also tend to spend more effort in stage 2, for instance because there are simply "more aggressive" participants, then this could have caused intra-alliance efforts to be higher in the *Fight* treatment than in the *FightNH* treatment. In our data, however, there is not much evidence for such a selection bias. One would expect that, in estimation (3) in Table 4, the coefficient of $x_{it} - \bar{x}_t^{A,B}$ is significantly positive (players who spent more stage 1 effort than the average alliance player

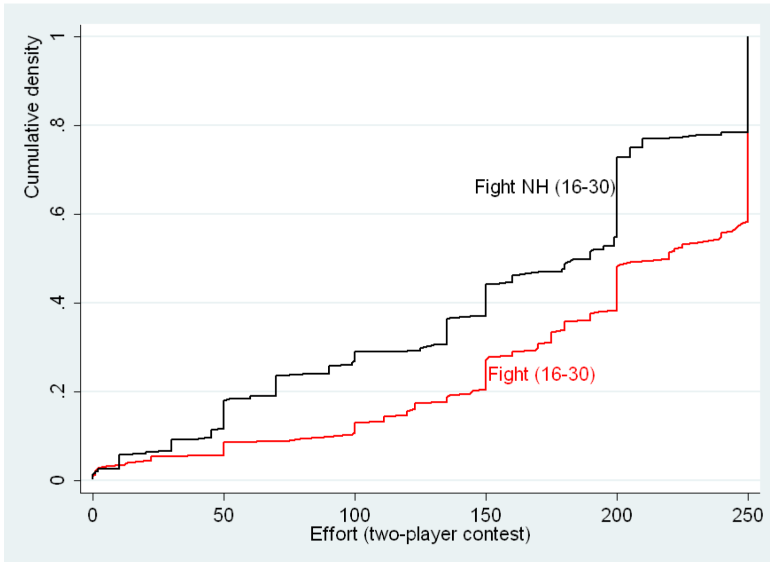

Figure 4: Distribution functions of stage 2 effort (rounds 16-30).

in the respective round expend higher effort in stage 2); however, we observe small negative coefficients which are not significantly different from zero.

Second, since the individual willingness to take risk (variable "RiskTaking") significantly and consistently explains effort choices, we can also test if the average type in stage 2, measured by "RiskTaking", differs from the average type in stage 1 of the *Fight* treatment. Indeed, this seems to be the case, although the difference is very small: the average risk type is 5.27 in the entire sample of *Fight* and 5.39 in the subsample of observations in stage 2 and periods 16-30 (recall that the willingness to take risks is measured on a scale from 0 to 10). Given the estimated coefficient of "RiskTaking", however, this small difference cannot explain that effort in *Fight* is higher by 40 points.

Third, in the exit questionnaire, we asked the participants (alliance players of the *Fight* treatment and all participants of the *FightNH* treatment) whether or not they "absolutely tried to win on their own" in the two-player contest. Taking the answer to this question as a proxy for "aggressiveness", those who said yes indeed spent significantly more effort in stage 2 than those who said no.[29] There is, however, no difference between the average "type" of players measured by this question in the entire sample in the *Fight* treatment compared to the subsample of observations in stage 2 (81.3% compared to 82.1% agreement). Overall, although a selection effect could be an explanation for our results we do not find much evidence that a selection bias causes the treatment effect of FIGHT.[30]

An alternative explanation for why efforts in the *Fight* treatment are higher is the "sunk cost fallacy", caused by the cost of effort expended in stage 1. A sunk cost problem would suggest that, in estimation (3) of Table 4, $\left(x_{it} - \bar{x}_t^{A,B}\right)$ $\times$FIGHT has a positive effect on stage 2 effort. This is not the case in our estimation. In the *Fight* treatment, players who have spent more than average effort in stage 1 are not more likely to spend more in stage 2 to recover the cost of stage 1 effort. This is mild evidence, but not proof that the sunk cost fallacy is not the reason for high effort in stage 2 of the *Fight* treatment. In our setting, the cost incurred in stage 1 is not exogenous, but chosen by the participants themselves. Hence, players who know that they usually feel a strong sunk cost problem may have reduced their stage 1 effort in anticipation of the situation they would face in stage 2 and in order to be less committed in stage 2. This endogeneity makes it difficult to properly measure the effect of the stage 1 effort costs on stage 2 effort. However, the distribution of efforts in the *Fight* treatment compared to the *FightNH* treatment, as shown in Figure 4, yields some evidence in line with the hypothesis that some players follow the sunk cost fallacy: Compared to *FightNH*, a much larger share of participants choose the maximum effort

[29] The Spearman correlation coefficient relating average individual effort in the two-player contest and the individual answer to the question on the will to win is 0.293 (p-value is 0.046) for the *Fight* treatment and 0.365 (p-value is 0.079) for the *FightNH* treatment.

[30] Given that the contest success function is probabilistic and given the interdependency of the alliance players, higher effort by an alliance player does not necessarily lead to a victory in the inter-alliance contest, which weakens the problem of a selection bias.

level (250) allowed in the Fight treatment. This could be an indication of an attempt to recover the cost of effort already paid in the inter-alliance contest.

When an individual expends the maximum effort, this leads to the highest likelihood of winning the prize and being compensated for the stage 1 effort cost. This positive experience might make it more likely that he/she again chooses maximum effort (i.e., a 'reinforcement effect'), which might be a potential explanation for the much higher fraction of effort choices at the upper bound in the *Fight* treatment. This conjecture is supported by the data: For individuals in *Fight* who have chosen maximum effort in the previous internal fight and won with this effort choice, it is more likely that they again choose maximum effort in the next internal fight they play, compared to the case in which they lost with an effort choice of 250.[31] In *FightNH*, there is no such effect of the history and there are also much less choices at the upper bound. This evidence of a 'reinforcement effect' from winning with an effort choice at the upper bound in the *Fight* treatment supports the interpretation that the high effort choices in *Fight* are driven by an attempt to minimize the likelihood that the stage 1 effort was in vain.

To summarize our findings on the effect of a joint history, even if there is a considerable amount of heterogeneity across subjects, our evidence suggests that the positive effect of a joint history on internal fighting intensity is not driven by a selection effect of more "aggressive" subjects in the *Fight* treatment, but is more likely to be a "sunk cost fallacy".[32] Returning to the question of whether a brother-in-arms effect helps alliances to reduce rent dissipation in the internal conflict, we can clearly reject the hypothesis that

[31] In a random-effects logistic regression, which estimates the probability $\Pr(y_{i,t} = 250 \mid y_{i,t-k} = 250)$ as a function of a dummy variable indicating victory in round $t-k$ and of other control variables, the estimated coefficent of this dummy variable for victory in round $t-k$ is positive (the marginal effect is 0.20) and significant at the 10%-level in the *Fight* treatment. ($t-k$ indicates the round of the previous two-player contest before t that i played; hence k can be integers bigger than 1 in *Fight* treatment, but $k = 1$ in *FightNH* treatment.)

[32] However, this does not mean that the sunk cost fallacy is the only reason that could make alliance players fight more fiercely than if there were no joint fighting history.

alliances succeed in achieving such a brothers-in-arms effect. This result can provide a basis for further analysis of whether factors which are absent in our setting might favor the emergence of in-group solidarity effects and their persistence, even after the alliance has been dissolved.

5 Conclusion

We studied the generic strategic setup of an alliance: players who fight jointly against a common adversary for a prize, and who, if they win, may fight about how to divide the prize between them. As one of the main research questions, we considered how formerly fighting shoulder-by-shoulder as 'brothers in arms' affects players' behavior once they become adversaries, i.e., after the break-up of the alliance. Using experimental data, we tested two competing hypotheses. On the one hand, the in-group solidarity that has been described for groups fighting against an out-group may suggest that former 'brothers in arms' fight less vigorously against each other than strangers. On the other hand, a rational choice theory that is based on monetary incentives suggests that a common history as 'brothers in arms' should make no difference for the behavior in the internal fight. The experimental data reject the idea that in-group solidarity survives the break-up of the group: former members of an alliance fight even more vigorously against each other than strangers.

A second question considered mobilization of alliance effort. We asked whether an alliance can mobilize more total alliance effort if its members share the prize of victory equally and peacefully than if its members anticipate that they have to fight about how to divide this prize. An answer to this question takes the answer to the first question on board and anticipates that former 'brothers in arms' will fight vigorously when dividing the spoils of victory. We would then expect that alliances with rules that ensure that they peacefully share the prize should be able to mobilize more alliance effort. This is also what we find in the experiment - not for inexperienced players, but for players who have gathered some experience. As has been reported by political scientists for cases of military alliances, such alliances often break up after victory and enter into vigorous fighting. We show that the possible break-up of a victorious alliance and the vigorous fighting between former members of the same alliance is a serious strategic drawback of alliances. Institutions or other arrangements that eliminate such intra-alliance conflict could considerably strengthen alliances and their success. By and large, our analysis corroborates the anecdotal evidence that has been reported by political scientists about the strategic disadvantages of alliances.

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A Experimental Instructions (a sample for the *Fight* treatment)

Welcome to this experiment! Please read these instructions carefully and completely. Properly understanding the instruction will help you to make better decisions and, hence, earn more money.

Your earnings in this experiment will be measured in Talers. At the end of the experiment we will convert the Talers you have earned to cash and pay you in private. For each **45 Talers** you earn you will be paid **1 Euro** in cash. Therefore, the more Talers you earn, the more cash you will gain at the end of today's experiment. In addition to the Talers earned during the experiment, each participant will receive a show-up fee of 4 Euros.

Please keep in mind that you are not allowed to communicate with other participants during the experiment. If you do not obey this rule you will be asked to leave the laboratory and will not be paid. Whenever you have a question, please raise your hand; an experimenter will come to you.

A.1 Your task

This experiment will consist of 30 rounds. Before the actual experiment starts, you will first have to answer a few questions related to the experiment. The questions will be presented to you through the computer screen. For the experiment, groups consisting of three people are formed. These groups are randomly composed in each round. Your task in each round is to make some decisions. The money you earn depends on your decision and the decisions of the two other players in your group.

Let the three players in one group be called A, B, and C. In each round, three players A, B, and C compete for a prize of 450 Talers. The competition works as follows:

1. Two players A and B form an "alliance". Player C is playing on his

own.

2. Your role in the experiment will be either that of player A, B, or C. This role will be randomly assigned to you. Each participant will keep his role throughout the entire experiment.

3. In a first stage, all players will simultaneously choose "an effort level". Each player decides independently on his own effort level. A player's effort is chosen as an integer between 0 and 250, and it corresponds to the amount of Talers the player would like to expend in the competition to win the prize. You will have to pay this amount of Talers to the lab, whether or not you win the competition. In the following, player A's effort is denoted by X_A, player B's effort is denoted by X_B, and similarly player C's effort is denoted by X_C.

4. Then, you will be shown the amount of Talers that the other players in your group have expended. The efforts of player A and B will be added up and the sum of X_A and X_B corresponds to the effort that the alliance of players A and B spends on the competition. The total expense is equal to the sum of all players' efforts: $X_A + X_B + X_C$.

5. Now a fortune wheel will turn and decide whether the alliance consisting of A and B or whether player C wins the 450-Taler-prize. As you will see, the fortune wheel is divided into two colors - red and blue. The red color represents the total Talers spent by player A and B (i.e., $X_A + X_B$). The blue color represents the Talers spent by player C (i.e., X_C). The two colored areas on the wheel represent exactly their shares in the total expense (i.e., $X_A + X_B + X_C$).

6. At the centre of the fortune wheel there is an arrow initially pointing to the top. After some time the arrow starts to rotate and then stops randomly. If the arrow stops in the red-colored area, players A and B win the prize. If the arrow stops in the blue-colored area, player C

wins the prize. This means that the probability that players A and B win the prize is equal to their share of their joint effort in the total expense, hence

$$\text{probability that } A \text{ and } B \text{ win} = \frac{\text{effort } X_A + \text{effort } X_B}{\text{total expense } X_A + X_B + X_C}.$$

Equivalently, the probability that player C wins the prize is equal to the share of C's effort in the total expense:

$$\text{probability that } C \text{ wins} = \frac{\text{effort } X_C}{\text{total expense } X_A + X_B + X_C}.$$

For your information, the probabilities that either the alliance of A and B or player C wins the competition will be displayed to you.

Therefore, each player's probability of winning depends not only on his own expenditure in the competition but also on the expenditures of the other players in the group. Note that the more Talers a player spends, the more likely it is that he wins the competition. More effort expended, however, means that a player has to pay more Talers to the lab.

7. If none of the players expends any Taler, i.e., $X_A = X_B = X_C = 0$, then it is equally likely that either the alliance A and B or player C wins. If players A and B both do not expend any Taler, but player C expends at least one Taler, player C wins the competition. If player C does not expend any Taler, but either player A or player B (or both) expends at least one Taler, the alliance A and B wins the competition.

8. Every player has to pay his effort (in Taler) to the lab, irrespectively of the outcome of the fortune wheel. Therefore, your earnings per round will be calculated as your gain in the competition minus your effort: earnings=gain-effort.

- If player C wins, the competition ends and he gets the 450-Taler-prize; players A and B will gain nothing. While players A and B do not have any gain, but have to pay their efforts, the earnings of player C are calculated as follows: C's earnings = 450 – X_C.
- If the alliance of A and B wins the competition, then players A and B have to compete with each other again for the prize of 450 Taler. The procedure of this competition is exactly the same as described above when the alliance players A and B compete against player C for the prize. At first, A and B have to decide simultaneously and independently about the amount of Talers they would like to expend to win the prize of 450 Taler. The effort, again, is chosen as an integer between 0 and 250, and it has to be paid to the lab in addition to the efforts already paid (X_A and X_B), whether or not the player wins the competition.

  In the following, these new efforts of A and B are denoted by Y_A and Y_B (Note that these efforts are only chosen if the alliance of A and B has won against player C). Again, a fortune wheel will determine the winner. The probability that A wins the prize of 450 Taler will be:

$$\text{Probability that } A \text{ wins} = \frac{\text{effort } Y_A}{\text{total expense } Y_A + Y_B}$$

  Equivalently, the probability that player B wins, will be:

$$\text{Probability that } B \text{ wins} = \frac{\text{effort } Y_B}{\text{total expense } Y_A + Y_B}$$

  Therefore, each player's probability of winning now depends only on the efforts in this new competition. The yellow-colored area on the lottery wheel will denote the share of A's effort in total expense $Y_A + Y_B$, the green-colored area denotes the share of B's effort in total expense. The arrow will rotate again to decide whether A or B wins the prize.

Hence, in the case that players A and B won the competition against player C before, the earnings of players A and B are calculated as follows:

- In the case that A *wins* against B, B has to pay both his efforts X_B and Y_B, and does not receive any gain. A's earnings in this case will be: A's earnings $= 450 - X_A - Y_A$.
- In the case that A *loses* against B, player A has to pay both his efforts X_A and Y_A, and does not receive any gain. B's earnings will be: B's earnings $= 450 - X_B - Y_B$.
- In both cases, player C receives no gain but has to pay his effort X_C,which he expended in the first competition.

A.2 Procedure

The experiment will consist of 30 identical rounds. In each round, you will have the same role (player A, B, or C). The other two players in your group will be randomly assigned to you in each round.

You will not know who the other players in your group are. All the decisions you make will remain anonymous, and any attempt to reveal your identity to anyone is prohibited. After the experiment, you will be asked to answer some questions, including some personal information (e.g., gender, age, major...). All the information you provide will be kept anonymous and strictly confidential.

At the end of today's experiment, we will **randomly choose 6 out of the 30 rounds** for which to pay you. Your total earnings in those 6 rounds will be added up, converted to euros, and paid to you in cash. This means that the earnings of all other rounds will not be paid to you and that you do not have to pay the efforts of these rounds either. You will get to know which

6 out of the 30 rounds will be chosen only after finishing these 30 rounds.

Moreover, you will receive **0.60 euros** for each of the 30 rounds you have played. The sum of this payment of 0.60 euros per round and your earnings from the 6 rounds of the experiment selected for payment will determine your total earnings in today's experiment.

Before the experiment starts, we will ask you some questions (which are related to the actions in the experiment) through the computer screen.