Introduction

The formation of an alliance is typically embraced as a signal of political success. Psychologists offer explanations for this positive attitude towards alliances in conflicts. 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 emphasized the importance of group spirit. Campbell (1965, p.293), for instance, 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' or possibly by behavioral norms.[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 a higher collective fighting effort. But each member should prefer the additional effort to be expended by other members of his group.

The members of an alliance face a second major strategic problem. If the alliance is victorious, they may quarrel about dividing the spoils of victory. The effort expended in this internal distributional conflict reduces the value they attribute to this prize. This future effort should further discourage alliance members at the stage when they decide about their contribution of effort to the inter-alliance conflict.[3]

Anecdotal evidence suggests that these psychological effects as well as rational choice considerations may be at work. Moreover, the formation and resolution of alliances is a dynamic phenomenon, and each cause of conflict is full of idiosyncrasies. Empirically it is difficult to distinguish these effects and measure their size. 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, on purpose, 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 issue of contributing effort for the alliance. We ask: how important is the perspective that future redistributional conflict within a victorious alliance reduces the value of winning? Does this possible 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 this conflict cannot emerge? Second, we address some of the possible psychological effects of in-group and between-group dynamics. We ask: how does the alliance members' experience of successfully fighting shoulder-to-shoulder affect their willingness to turn against each other when they have to solve the distributional conflict between them?

Our general framework consists of 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 of a given size. If the single player wins, he takes the reward and the game ends. If the alliance wins, the alliance players need to share this reward. We consider two different - exogenously imposed- sharing regimes. In one regime the alliance members split evenly the gains from winning. In a second regime the alliance members have to fight about how to distribute the gains from winning between them. The comparison of these two regimes yields an answer to one of the key questions: do brothers in arms behave differently if they anticipate future conflict between them? Moreover, we compare the contest efforts among members of the winning alliance if they fight internally about the division of the reward with the efforts in a similar two-player contest among strangers. In this way, we can answer the question of whether having jointly defeated an enemy affects behavior in the process of dividing the spoils.

Our results are only partially in line with the rational choice theory of alliance formation, but we also do not find strong evidence in support of intra-group solidarity. Members of an alliance expend much more effort in the conflict with outsiders than would be predicted by the classical theory of contests. This high effort is seemingly independent of whether the members of a victorious alliance face a wasteful distributional conflict within the group or not. Moreover, we find little evidence that the joint experience of fighting side-by-side in an alliance against a joint enemy reduces the alliance members' mutual hostility when it comes to dividing the spoils of victory.

The different effects which we isolate and quantify in the laboratory can be illustrated by anecdotal evidence for wars. Free-riding, opportunism and strategies of burden shifting among allies have been discussed.[4] Many writers also emphasize a high potential for the break-up of the alliance when defeat of the enemy is imminent. For the First World War, Bunselmeyer (1975, p.15) claims:

> The British also disagreed with the French over economic policy. To be sure, the two Allies cooperated on economic matters during most of the War, and they were the principal sponsors of the Paris Economic Revolutions. However, their cooperation dissolved as victory became certain and reparation and indemnity replaced other wartime planning. Thereafter, they became the principal competitors for shares of compensation from Germany.

A similar observation has been made for the Napoleonic War (O'Connor 1967, p.369). And 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 frequently cited example for former alliance members turning against each other and fighting about the spoils of war. 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."[5] Taken together, historical evidence suggests that victorious alliances may collapse after having achieved their primary goal, and the former allies start fighting with each other about the spoils of war. As Beilenson (1969, p.193) concludes: "Among victors, alliances have tended to dissolve at the peace table in quarrels over the spoils." But how does the anticipation of this future conflict affect their behavior during the war? And how does the joint fighting experience affect their fighting behavior after the breakup of the alliance? These are the focal questions in our empirical analysis.

There is no experimental work that we are aware of that addresses the strategic effects of future conflict among current alliance members, nor on the possible solidarity effect of having previously been 'brothers in arms' if they have to fight about dividing the spoils. However, structurally related questions have been addressed in the context of groups making contributions to a group-specific public good. In particular, a small literature compares contributions to a public good in inter-team conflicts. These include Gunnthorsdottir and Rapoport (2006), Abbink et al. (2010), Ahn et al. (2010), and Kugler et al. (2010). This last paper is framed as a public good game, but structurally it analyses what is, in essence, an asymmetric contest between an alliance and an adversary who is a single person. Sheremeta and Zhang (2010) consider contests between teams and compare their efforts with efforts in single-player contests. They allow for communication between members of the same team. While single players and teams over-expend effort compared to the theory prediction, teams expend somewhat less effort. These papers cover the problem of free-riding, but they do not address a possible conflict within the victorious group and its consequences 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. This very large body of literature cannot be surveyed here, but few contributions in this literature consider multi-stage contests. Sheremeta (2010) considers multi-stage elimination contests among single players. His conclusion about the intrinsic value of winning as a motivational factor may also be indicative for explaining some of our results. None of this literature addresses the role of future conflict among players at the stage in which they are 'brothers in arms', nor whether their joint history moderates their internal fighting.

Theoretical Setup

Consider a contest among three players A, B, and C who compete for a common prize of value V by expending effort. Players A and B join their forces and form an alliance AB to compete with player C. If player C wins, he gets the prize. If the alliance AB wins, the prize value has to be shared among players A and B. In this paper, we focus on two most common sharing rules: the equal-sharing rule and the contest-sharing rule. If the equal-sharing rule applies, each of the players A and B gets one half of the prize value, independently of the effort that players A and B expended in the contest with player C. If the contest-sharing rule applies, players A and B compete for the prize by again expending effort in an intra-alliance contest between them. The sharing rule is exogenously given and assumed to be common knowledge to players A, B and C when they enter into the contest.

We consider the following contest success function for describing how players' efforts translate into win probabilities. Let (x_A, x_B, x_C) be the players' efforts in the contest between the alliance AB and C. Then, the probability that the alliance AB wins this contest is equal to

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

and the probability that 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.[6] Costs of efforts are equal to a player i's effort x_i, $i \in \{A, B, C\}$. Therefore, 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 is player i's expected prize value if the alliance wins the inter-alliance contest, for $i \in \{A, B\}$, which depends on the prize-sharing rule. If player C wins, he gets the entire prize, thus $v_C = V$.

Case 1: Equal sharing If players A and B simply split up the prize equally in case they win against C (and they can commit to this sharing rule), $v_A = v_B = V/2$. If the alliance players choose their effort non-cooperatively and each player maximizes his expected monetary payoff given in (2) and (3), respectively, this results in equilibrium efforts

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

Here, due to the assumptions on the alliance players' efforts, only the sum $x_A + x_B$ is uniquely determined in equilibrium. The sum of efforts $(x_A + x_B)^*$ is smaller than player C's equilibrium effort x_C^*. As the expected prize value for each alliance player is lower than the prize value for the single player, they do not expend more effort than the single player. Moreover, due to the free-rider problem, the alliance players even together expend less effort than the single player. Expected equilibrium payoffs are

$$(E\pi_A + E\pi_B)^* = \frac{2V}{9} \text{ and } (E\pi_C)^* = \frac{4V}{9} \tag{5}$$

where again only the sum of player A and B's payoff is uniquely determined. The alliance's joint payoff is even smaller than the payoff of the single player.[7]

Case 2: Internal fight If the alliance players cannot commit to sharing the prize peacefully in case they win the contest, this can result in an internal fight. This intra-alliance contest follows the same rules of the lottery contest. If A and B's effort in this second contest is denoted by y_A and y_B, then A's probability of winning this intra-alliance contest is

$$q_A = \begin{cases} \dfrac{y_A}{y_A + y_B}, & \text{for } y_A + y_B > 0 \\ \dfrac{1}{2}, & \text{for } y_A + y_B = 0 \end{cases} \tag{6}$$

and B's winning probability is $q_B = 1 - q_A$. In case player $i \in \{A, B\}$ wins this second contest, he obtains the entire prize V. Both players, however, have to pay their cost of effort, which is equal to y_i.

If the alliance AB wins the contest against C and players A and B fight about the prize V, their expected payoffs in this subgame are $q_i V - y_i$, and the equilibrium efforts in this intra-alliance contest are therefore equal to

$$y_A^* = y_B^* = \frac{V}{4}. \tag{7}$$

Thus, they obtain an expected payoff (net of effort cost) in this second contest 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 prize value (net of effort cost) from winning against C is equal to $V/4$ (i.e., $v_A = v_B = V/4$) which is only half of their expected prize value in Case 1 where they share the prize peacefully. Consequently, the alliance players' effort in the contest against C decreases. Equilibrium efforts in the contest between AB and C are

$$(x_A + x_B)^* = \frac{V}{25} \text{ and } x_C^* = \frac{4V}{25}, \tag{8}$$

In total, expected payoffs are equal to

$$(E\pi_A + E\pi_B)^* = \frac{3V}{50} \text{ and } (E\pi_C)^* = \frac{16V}{25}. \tag{9}$$

Here, the difference between expected payoffs of alliance players and the single player becomes even larger: potential internal fight about the prize identifies a second important reason why forming an alliance in contests may not be desirable.

The Experiment

Our experiment is composed of four treatments that measure the effect of internal conflict, on the one hand, and test for the importance of 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 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.[8] Having followed the outcome of the fortune wheel, subjects were given their profits in this 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.

The second treatment, called *Share900*, deviates from treatment *Share* in only one respect: the prize that is handed out to the winner(s) is 900 instead of 450. Consequently, the effort choices are from the set $\{0,1,2,...,500\}$. This treatment is mainly designed as an internal validity test, to see whether the effort choices would also double.

A third treatment, called *Fight,* is also identical to treatment *Share*, except that the alliance players have to engage in an intra-alliance contest to determine who gets the full prize if they win the contest against player C. So, if the alliance of players A and B wins the prize against C, then the game 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 effort choice of alliance players in inter-alliance contest is influenced by the intra-alliance prize sharing rule.

The fourth treatment *FightNH* ("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.

Treatment	Share	Share900	Fight	FightNH
Prize	450	900	450	450
Players	AB⇔C	AB⇔C	AB⇔C	A⇔B
Prize sharing (between A and B)	50, 50	50, 50	Contest	Contest
$(x_A + x_B)^*$, x_C^*	(50, 100)	(100, 200)	(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)	(200, 400)	(27, 288)	–
$(E\pi_A)^*$, $(E\pi_B)^*$	–	–	–	(112.5, 112.5)

Table 1: Treatment specifications.

Table 1 gives an overview of the four treatments. Columns 2-5 describe the characteristic features of these treatments and surveys 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 2010. Each experimental session involved 24 student-subjects playing one out of the four treatments. The data was collected from three sessions each for treatment *Share*, *Share900*, and *Fight*, and one session for treatment *FightNH*. Overall, 240 subjects participated in the experiment. They were students from all fields of study.[9] Each subject played only one treatment and had a fixed role in this treatment (either player A or B, or player C). This role (as A, B or C) was randomly assigned by the computer programme. The rules of the respective treatment were known to all players. Subjects were randomly divided into subgroups of six subjects in treatment *Share*, *Share900*, and *Fight*, and subgroups of four subjects in *FightNH*. Each treatment consisted of 12 rounds, and subjects kept their assigned roles throughout these rounds. However, subjects were randomly rematched within their subgroup in each round (in order to avoid repeated interaction behavior). Each subgroup can be used as a single independent observation.[10]

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 answered the testing questions. At the end of the experiment, the subjects had to fill in a questionnaire. At the end of their session, each subject was paid separately and in private. In addition to a fixed payment of 0.6 EURO that they received for each round, the subjects were also paid a 4 EURO show-up fee, plus their profits in 3 rounds randomly drawn out of 12 rounds. On average, the subjects earned 14 EURO, and in total a session took about one hour.

Hypotheses and Main Results

The main questions that motivated 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 about the prize among themselves.*

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. Hence, Hypothesis 1 is fully compatible with the idea of out-group hostility and with an in-group solidarity effect emphasized by psychologists.

The second hypothesis concerns the role of a 'brothers in arms' experience for the intensity of fighting between the members of a victorious alliance for 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, controlling for selection effects. 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.*

The competing hypothesis is:

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

The anecdotal evidence of the break-ups of war alliances at the end of war and the intensity of the Cold War suggests that data are in line with Hypothesis 2a. The psychology of in-group solidarity suggests that Hypothesis 2b may hold.

Before turning to the assessment of these main hypotheses, it is reassuring to note that the individuals in the experiment exhibit many characteristic patterns that are known from other contest experiments.

First, it is well documented that individuals in lottery contests expend more effort than what would be desirable for individuals who maximize their monetary payoffs. Individuals in our experiment also show this pattern. This is true, in particular, for treatment *FightNH*, which is a standard symmetric lottery contest between two contestants. It also shows up in all other treatments. Table 2 provides the dissipation rates (defined as effort expenditure compared to the monetary value of the prize) observed in the experiment, compared to their theoretical predictions for all treatments. In equal-sharing treatments (*Share* and *Share900*), subjects overall dissipate more than 60% of the prize value when the equilibrium prediction is only 0.33. In *Fight* treatment, subjects should only expend 20% of the prize value in inter-alliance contest, given that alliance players will face a second-stage contest if they win. However, we still observe a dissipation rate of 66% for experienced behavior (rounds 7-12). In the second stage of the *Fight* treatment, the former alliances expend similar effort (76% of the full prize) as what is dissipated in *FightNH* treatment. This higher-than-predicted effort is a common phenomenon in contests, and has been explained, e.g., by an intrinsic benefit of winning (Sheremeta 2010).

Average Rate of Dissipation (total effort/prize)				
Treatment	stage	Prediction	Actual rate	
			period 1-12	period 7-12
Share		0.33	0.62	0.63
Share900		0.33	0.65	0.64
Fight	stage 1	0.20	0.70	0.66
	stage 2	0.50	0.69	0.76
FightNH		0.50	0.75	0.80

Table 2: Average dissipation rate by treatment.

Second, the treatment *Share* is fully congruent with one of the treatments in Gunnthorsdottir and Rapoport (2006) both in its structure and as regards the empirical results. Alliance players and the outgroup player C overexpend efforts compared to the narrow equilibrium predictions, and alliance players can achieve higher joint efforts rather than the lower joint efforts that would be predicted by the free-riding problem they face. Hence, when turning to the more innovative treatments with intra-alliance fighting, there is some reason to trust that our subject pool is not systematically different from subject pools in other contest experiments.

Third, a comparison between the two *Share* treatments shows that players neatly respond to monetary payoffs. Doubling the prize value actually leads to roughly doubling the respective efforts. While players may follow other objectives in addition, monetary payoffs seemingly matter. Descriptively, the similarity of the treatments *Share* and *Share900* is illustrated in the left panel of Figure 1.

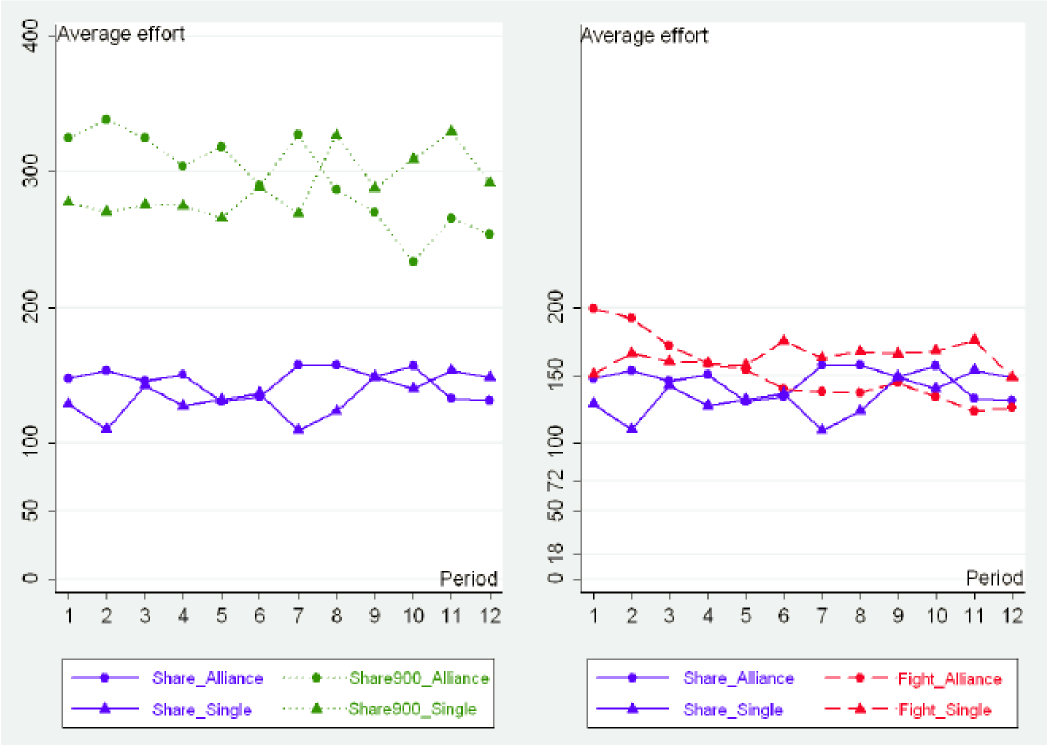

Figure 1: Average effort (alliance and single player) by treatment and period.

Hypothesis 1 Let us now turn to the first main Hypothesis, starting with a descriptive analysis. In the right panel of Figure 1 we plot the time series average effort in the treatment *Fight* and *Share*. The alliance players (A and B) expend together about the same effort in the *Fight* as in the *Share* treatment. This does not support the hypothesis that if an internal fight is followed by the victory of the alliance, alliance players should expend much less in the inter-alliance contest. Single players' behavior also does not differ for the two treatments, which is consistent with the invariance of alliance players' joint effort across treatments.

A multilevel mixed-effect model can test whether effort choices differ across treatments. The dependent variables are the effort/prize ratio (1) for the individual alliance player and (2) for the single player in each treatment. Apart from treatment dummies, to control for learning effects, we include a time dummy into the estimation, indicating whether observations are from the first half of the experiment, and we interact this time dummy with the treatment dummies. Moreover, we include both group-specific and individual-specific error terms to control for group and individual heterogeneity. The equation we estimate is:

$$x_{ijt} = \beta_0 + \beta_1 * Share900 + \beta_2 * Fight + \beta_3 * t(1..6)$$
$$+ \beta_4 * Share900 \times t(1..6) + \beta_5 * Fight \times t(1..6) + \mu_i + \nu_{ij} + \varepsilon_{ijt}$$

The random effects are estimated through a group-specific error term (μ_i) and an individual-specific error term (ν_{ij}). The covariates we estimate in the fixed effect are five dummies: *Share900, Fight, t(1..6), Share900*$\times$*t(1..6),* and *Fight*$\times$*t(1..6).* The constant measures average effort in periods $7-12$ in the *Share* treatment, and *Share900* and *Fight* estimate the respective treatment effect comparing data across treatments in the second half of the experiment. Moreover, for the *Share* treatment, *t(1..6)* measures the difference in efforts between the first and second half of the experiment; *Share900*$\times$*t(1..6)* and *Fight*$\times$*t(1..6)* compare effort in periods $1-6$ and the respective treatment to the base category (*Share*, periods $7-12$).

Model	(1)	(2)
specification	alliance players (A or B) only	single players (C) only
Dependent Var.	$\text{Effort}_A/\text{Prize}$ or $\text{Effort}_B/\text{Prize}$	$\text{Effort}_C/\text{Prize}$
Constant	0.164***	0.305***
	(0.016)	(0.025)
Share900	-0.012	0.031
	(0.022)	(0.035)
Fight	-0.015	0.061*
	(0.022)	(0.035)
t(1..6)	-0.004	-0.017
	(0.008)	(0.013)
Share900$\times$t(1..6)	0.016	0.018
	(0.022)	(0.035)
Fight$\times$t(1..6)	0.028	0.071**
	(0.022)	(0.035)
Random-effect:		
Level-1 (group)	0.036	0.021
	(0.009)	(0.053)
Level-2 (subject)	0.072	0.109
	(0.006)	(0.014)
Residual:	0.091	0.112
	(0.002)	(0.003)
Total observations	1728	864
Log likelihood:	1520.255	573.223
Wald $\chi^2_{(5)}$	37.44***	10.95 *

Note: Standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. Observations in *Share* treatment from period 7-12 are taken as the baseline group.

Table 3: Multi-level random effect models on efforts in the first stage.

Table 3 presents the results of both regressions. Alliance players (model 1) each put in an effort equivalent to around 16.4% of the prize value when they jointly play against the single player. In the second half of the experiment (i.e., periods 7-12), there is no significant treatment effect either for the *Share900* or for the *Fight* treatment; this also holds for the first half of the experiment. The single players (as shown in model 2) expend roughly twice the effort of each alliance player (i.e., 30.5% of the prize value). This leaves the alliance and the single player almost an equal *ex post* chance of winning the prize. Single players initially expend slightly higher effort (7% more) in the *Fight* treatment than in the other treatments, this difference, however, is only weakly significant in the second half of the experiment. There exists quite some heterogeneity (on the group and individual levels) both among alliance players and among single players, as in both regressions more than 50% of the error term is due to μ_i and v_{ij}.[11] In summary, we find that, contrary to the theory, alliance players jointly put in an effort similar to that of the single player, rather than much less effort. Moreover, the hold-up problem caused by future internal distributional conflict is seemingly not very severe, and thus we do not find support for Hypothesis 1.

In the light of Hypothesis 1, this is a strong and surprising result. Our analysis becomes exploratory when mentioning some possible reasons. First, players may derive some additional pleasure or satisfaction from winning, in addition to the actual monetary value of the prize (Sheremeta 2010). This enlarges their subjective valuation of winning. Second, in the *Fight* treatment, the repeated interaction between A and B within one round may generate incentives for players to use their effort contribution in the contest against C to signal their high 'desire for winning' by making high effort contributions, trying to discourage their co-player in the alliance in the subsequent intra-alliance contest.[12] This is particularly relevant if there is a considerable heterogeneity among players about this 'desire for winning'. A further explanation may also be related to non-monetary motivations, but is much simpler. Subjects may simply enjoy playing the lottery contest. Hence, if they can affect the probability for reaching stages in which they can play additional lottery contests (i.e., reach the subgame with the intra-group contest), then they may be willing to expend extra effort trying to reach these stages.

Question:	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?		
	Agree	Don't agree	Don't know
Share	31.25%	62.5%	6.25%
Share900	33.33%	66.67%	0%
Fight	47.92%	37.5%	14.58%

Table 4: Question on behaviour in the inter-alliance conflict.

Besides these possible reasons that might have caused high effort in the *Fight* treatment, there remains an additional factor that actually should have worked in favour of Hypothesis 1: one could have expected free-riding behaviour among alliance members to be stronger when they know that they will have to fight internally about the prize. This motive is indeed present in our experiment. We can confirm this by using the questionnaire that subjects had to fill in at the end of the experiment. There we asked, among many other questions, whether alliance players tried to free-ride on their co-players' efforts (see Table 4). While in the treatments with peaceful sharing of the price about 32% answered in favour of free-riding, this fraction increased to 48% in the *Fight* treatment.[13]

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 without a common history. We compare the effort choice in the second stage in the *Fight* treatment to the effort choices in the simple two-player Tullock contest (the *FightNH* treatment).

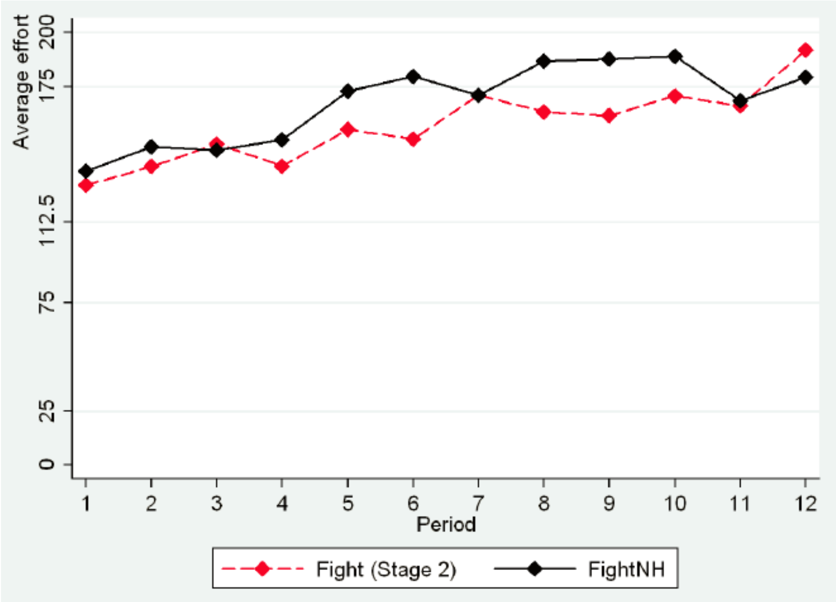

Figure 2: Average effort in two-players contest (Fight vs. Fight_NH).

Figure 2 presents average effort choices per period in both treatments. The two time series of average effort walk exactly shoulder-to-shoulder. At least, in aggregate levels we do not observe any difference between two alliance players and two total strangers. This is further confirmed by our regression results. Using the same multilevel mixed-effect model, we compare individual effort in the internal fight of *Fight* to effort in *FightNH*. As baseline category, we use effort in *FightNH* and periods 7-12, and we allow effort to change with three dummies: *Fight*, *t(1..6)*, *Fight*×*t(1..6)*. Following the same logic as above, the dummy *Fight* measures the 'brothers-in-arms' treatment effect in the second half, and the time dummy *t(1..6)* as well as its interaction with the treatment dummy control for learning effects. As shown in Table 5 (model 1) below, there is no significant treatment effect either. Subjects in both treatments tend to compete more aggressively in the second half of the experiment and expend on average 25 points more in period 7 to 12.

This result suggests that a common fighting history seemingly plays no major role for the subsequent intra-alliance contest. An actual difference may, however, be hidden in the data. The two treatments *Fight* and *FightNH* possibly differ along other important dimensions, and the effects of these other dimensions may just cancel with the history effect which one may have expected to find. One such effect is a possible selection bias in the intra-alliance contests. Players in the winning alliance may generally expend more effort than the average players. Their higher effort may be an indication of a higher intrinsic motivation for winning, which should carry over to the second stage and induce higher effort there, too. This selection effect may counteract the effect that former brothers in arms would be nicer to each other than strangers are. A second possible effect is the so-called "sunk-cost fallacy". If the subjects do not perceive the cost of their effort in inter-alliance contests as being sunk already, members in the winning alliance may want to try to put more effort in hoping that the winning of the grand finale could recover all their current and previous cost. Therefore they expend more effort than they should even if they have already been nicer to their former partners.

Dependent Var.	Effort y_A or y_B		
Model	(1)	(2)	(3)
Constant	180.396***	180.396***	180.396***
	(14.763)	(14.627)	(14.658)
Fight	-7.907	-6.676	-5.422
	(18.558)	(18.431)	(18.518)
t(1..6)	-25.132***	-25.132***	-25.132***
	(5.944)	(5.890)	(5.824)
Fight×t(1..6)	1.578	-3.248	-8.769
	(8.844)	(9.006)	(9.115)
$(x_{it}-\bar{x}_t^{alliance})\times$Fight		0.0236	0.040
		(0.090)	0.090
$(x_{it}-\bar{x}_t^{alliance})\times$Fight×t(1..6)		0.212**	0.230**
		(0.104)	0.103
$(x_{-it}-\bar{x}_t^{alliance})\times$Fight			-0.056
			(0.081)
$(x_{-it}-\bar{x}_t^{alliance})\times$Fight×t(1..6)			0.299***
			(0 .104)
Random-effect:			
Level-1 (group):	29.335	28.762	28.910
	(7.718)	(7.751)	(7.751)
Level-2 (subject):	36.937	37.543	37.508
	(4.625)	(4.657)	(4.664)
Residual:	50.434	49.982	49.416
	(1.635)	(1.620)	(1.604)
Total observations	546	546	546
Log likelihood:	-2980.182	-2976.303	-2970.748
Wald(χ)	31.04***	39.44***	51.55***

Note: Standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. Observations in period 7-12 are taken as the baseline group.

Table 5: Multi-level random effect models on two-player contests.

Figure 3 (below) illustrates the relationship of alliance players' stage 1 and stage 2 effort in the *Fight* treatment. The horizontal axis shows average effort (in periods $7-12$) that a subject who was an alliance player expended in the competition with the out-group player, and the vertical axis plots this subject's average effort (in periods $7-12$) in the internal fight, provided that this stage is reached. Thus, subjects expending the same effort in both competitions would be located on the 45-degree-line. Most of the subjects chose higher effort in the second stage than in the first stage, which is in line with the theory prediction. A very high fraction of subjects chose the highest possible effort in the internal fight, which is clearly in contradiction to any effect of joint history of fighting. Only very few subjects chose much lower effort in the second stage competition than in the first stage; this behavior could reflect a 'brothers in arms' effect.

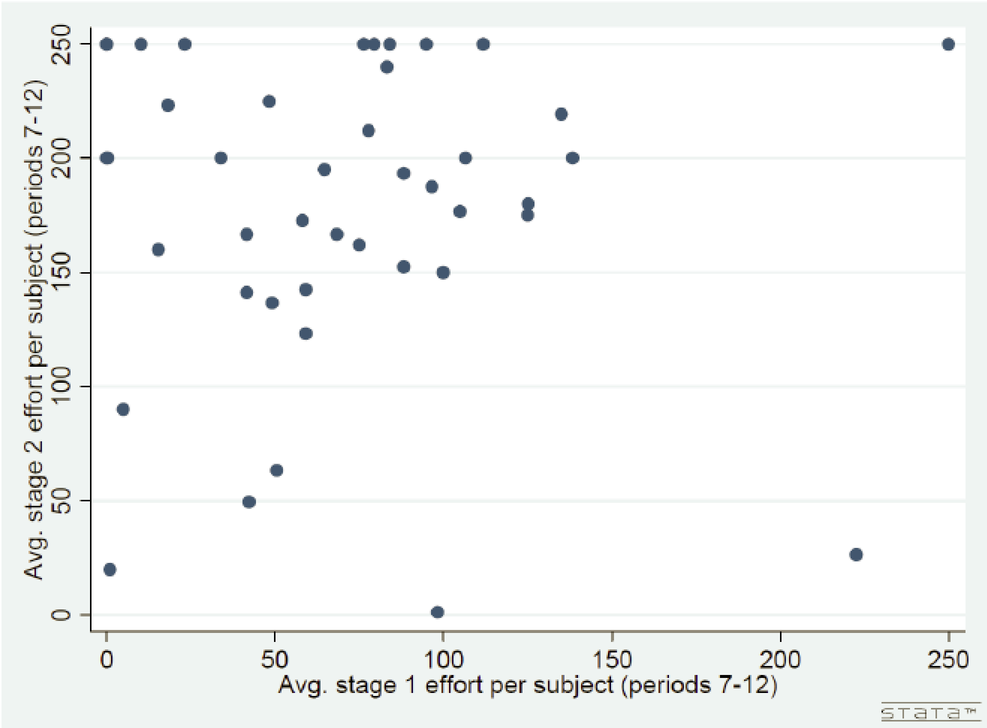

Figure 3: Comparison of stage 1 and stage 2 efforts in the *Fight* treatment.

In order to capture the effect of stage 1 effort in the *Fight* treatment, we include two further variables into the estimation. First, $x_{it} - \overline{x}_t^{alliance}$ measures player i's relative type by calculating the difference between his effort and the average effort of alliance players in period t. Second, $x_{-it} - x_t^{alliance}$ computes a similar measure for player i's co-player within the alliance in period t. In model 2 in Table 5, we include only $x_{it} - \overline{x}_t^{alliance}$ interacted with the dummies *Fight* and *Fight*$\times$*t(1..6)* into the estimation, while in model 3 we include both $x_{it} - \overline{x}_t^{alliance}$ and $x_{-it} - \overline{x}_t^{alliance}$, again as interaction terms.

The effects of a player's and his co-player's relative type turn out to be significantly positive, but only in the first half of the rounds of the experiment (periods $1-6$). Here, players who chose more effort than average in stage 1 also choose higher effort in the distributional conflict in stage 2. This means that contestants who compete harder in the first stage tend to also compete harder in the second stage. This could be explained both by a sunk-cost fallacy and by a selection bias (more aggressive types put more effort in both stages). Further, subjects who played against a more aggressive player in stage 1 choose higher effort in stage 2. This implies that subjects did not moderate their fighting effort vis-à-vis their fellow fighters who have helped them to win the first contest by being aggressive in the inter-alliance contest. On the contrary, they seem to infer from the higher stage 1 effort of their partners that higher effort is also more likely in the intra-alliance contest, and hence expend more effort as well. In these three models, the estimated treatment effect (*Fight*) is negative; the standard errors, however, are fairly high and the estimates are not statistically significant. Thus, we find evidence in favour of Hypothesis 2a, and we do not find a significant effect of joint history as stated in Hypothesis 2b, even after controlling for the selection bias, or the intrinsic joy of winning.

Question:	[When you won the competition against player C,] what was your goal in the [following] competition?					
Answer:	1: "In any case try to win myself."			2: "Keep efforts low such that I and my co-player have higher payoffs."		
Agree or not?	Yes	No	Don't know	Yes	No	Don't know
Fight	64.58%	31.25%	4.17%	37.50%	52.08%	10.42%
FightNH	75.0%	20.83%	4.17%	16.67%	54.17%	29.17%

Table 6: Question on behaviour in stage 2 of Fight and the contest of FightNH.

The variance of individual behaviour is quite high in the *Fight* treatment. Thus it may be difficult to identify a significant effect of joint history as brothers in arms from limited observations. Looking at the questionnaire that we conducted at the end of the experiment, we do find an effect of joint history. Asking the students for their goal in the two-player competition (the competition with player C in the *Fight* treatment and the stage-game competition in the *FightNH* treatment) we obtained the answers summarized in Table 6. In the *Fight* treatment, 65% of the subjects agreed that it was important for them to win on their own; in the *FightNH* treatment, this number increased to 75%. Similarly, in the *Fight* treatment 37.5% of the subjects agreed to the statement that they tried to cooperate with their co-player by choosing low effort; in the *FightNH* treatment, this attempt to cooperate was confirmed by only 16.7% of the subjects.[14] Including the subjects' answers to these two questions into the estimation shows that these different motives significantly explain the choice of effort in the internal fight.

Conclusion

We analyzed the strategic interaction within alliances. Our first result considers free-riding among members of the alliance who jointly fight against an outside enemy. Free-riding is far less pronounced than what would be expected from non-cooperative narrowly selfish behavior among the members of alliances. Even in the absence of repeated interaction, and in the absence of direct contact, communication or other means of exchange among alliance members, they expend very similar effort as unitary players who do not have a similar free-riding problem. This confirms previous results on fighting efforts of alliances.

Second, when fighting an outside enemy, 'brothers in arms' may already anticipate that success in the external conflict will be followed subsequently by future internal conflict about dividing the spoils of victory. Economic reasoning suggests that the subsequent conflict about dividing up the spoils should discourage alliance members from expending much effort in the contest against the external enemy. We show that this future fighting does not prevent alliance members from 'fighting shoulder-to-shoulder'. More formally, allies in a contest against an outside enemy expend, on average, the same amount of contest effort, irrespective of whether they have to share any spoils from conflict peacefully, or whether they can fight about the distribution of these spoils among themselves.

Third, former members of the same alliance fight vigorously against each other when dividing the spoils of victory. Comparing their efforts in this internal fight with the efforts expended by players in the same distributional conflict who do not have a common history as 'brothers in arms', we find very similar levels of effort and, in any case, no significant differences. This may suggest that possible solidarity among 'brothers in arms' when fighting against an outside enemy may rapidly depreciate or disappear as soon as the outside enemy disappears. The results are in line both with economic reasoning, and with the anecdotal evidence on the break-up of alliances at the end of the conflict with an external enemy discussed in the introduction. Comparing average effort per subject in the inter-alliance contest to this subject's effort in the intra-alliance conflict, however, suggests that there are several different motives driving individual behavior.

Overall, due to these properties, the collaboration in alliances is reasonably good, leading to higher success against lone enemies than one might predict. However, this success cannot obscure the fact that the material payoff of alliance members is low, compared to that of lone players.

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Appendix. 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 without getting 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 12 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.

   - In case 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 = $450 - X_C$.

   - In case the alliance of A and B wins the competition, then players A and B again have to compete with each other for the prize of 450 Taler. The procedure of this competition is exactly the same as described above when the alliance players A, 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. Again the arrow will rotate to decide whether A or B wins the prize.

Hence, in 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 expended in the first competition.

A.2 Procedure

The experiment will consist of 12 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** 3 **rounds out of** 12 to pay you. Your total earnings in those 3 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 3 out of the 12 rounds will be chosen only after finishing these 12 rounds.

Additionally to your earnings in these 3 selected rounds, you will receive **0.60 euros** for each of the 12 rounds you have played .

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

Endnotes

[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).

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

[4] 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."

[5] Cited in: Wilkins (2006, p.1136).

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

[7] 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.

[8] 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 stopped determined whether the alliance AB or player C won the contest.

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

[10] Random matching within a small group does not completely rule out that individuals are interacting with the same player in a future round. However, this random matching ruled out that players know that they are, or will be rematched with the same player in a particular round. Also the precise division of the subgroups was not explained to the subjects in the experiment. They were told that they would be randomly rematched with other players in each period and potentially they would play with and/or against different people in different periods. We believe that this design is a good compromise to balance the problem of repeated game effects and the quest for sufficient independent observations.

[11] Tests on the estimation of μ_i and ν_{ij} are both significantly different from zero. This further justifies our choice of the multilevel mixed-effects model.

[12] Repeated contests with incomplete information have been studied by Münster (2009), showing that the signaling problem is non-trivial.

[13] This difference is statistically significant. Moreover, including a variable containing this answer into the estimated equation on alliance players' effort shows that subjects having answered in favor of free-riding put significantly less effort in the inter-alliance conflict. This confirms that the subjects' answers are consistent with their behavior in the experiment.

[14] Answers to these two questions are highly negatively correlated. Agreement to the second question (on cooperation) differs significantly across the two treatments for the question, while the difference for the question of whether subjects have tried to win on their own is not statistically significant.