Escalation in conflict games: On beliefs and selection

Online Appendix

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This supplementary appendix to the article "Escalation in conflict games: On beliefs and selection" contains the following materials:

- Additional theoretical results:
  - Ranking of efforts in stage 2 (Section B.1)
  - Framework with probability weighting (Section B.2)
- Additional experimental results:
  - Escalation of efforts on average (Section B.3)
  - Accuracy of beliefs (Sections B.4 and B.5) and changes of beliefs across the stages (Section B.6)
  - Effort dynamics depending on the share of strong types in the matching group (Section B.7)
  - Efforts and beliefs in a supplementary treatment with fixed matching of player pairs (Section B.8)
- Experimental instructions for the treatments BASE and EXIT (Section C)

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B Supplementary material

B.1 Theory: Stage 2 properties

This section provides a partial characterization of the equilibrium in stage 2, which also illustrates why the complexity of the problem increases rapidly if we move from interaction at stage $s = 1$ to $s > 1$. At stage 2, there are four pairs of player valuation and player experience: $\mathbf{h}_{i,2} \in H_2 \equiv \{(v_H, x^*_{v_H}), (v_H, x^*_{v_L}), (v_L, x^*_{v_H}), (v_L, x^*_{v_L})\}$. A player with valuation v_i cares not only about her stage 2 opponent's valuation v_{-i} but also about $-i$'s matching experience, as both affect the opponent's effort choice (the latter through its effect on $-i$'s beliefs about the composition of the population). Bayesian updating yields the following stage 2 beliefs $\sigma_{\mathbf{h}_{i,2}}(\omega)$ of types $\mathbf{h}_{i,2} \in H_2$ about the true state of the world:[45]

$$\sigma_{(v_H,x^*_{v_H})}(\bar{\omega}) = \frac{1}{2}\frac{(1+2d)^2}{1+4d^2} > \sigma_{(v_H,x^*_{v_L})}(\bar{\omega}) = \frac{1}{2} = \sigma_{(v_L,x^*_{v_H})}(\bar{\omega}) > \sigma_{(v_L,x^*_{v_L})}(\bar{\omega}) = \frac{1}{2}\frac{(1-2d)^2}{1+4d^2}. \tag{40}$$

Compared to the stage 1 beliefs $\sigma_{\mathbf{h}_{i,1}}(\omega)$, the stage 2 beliefs of types $(v_H, x^*_{v_H})$ (with valuation v_H and experience $x_{-i,1} = x^*_H$) assign even more probability to the true state of the world being state $\bar{\omega}$ with many strong types (that is, $\sigma_{(v_H,x^*_{v_H})}(\bar{\omega}) > \sigma_{v_H}(\bar{\omega})$). The opposite effect emerges for types $(v_L, x^*_{v_L})$ where $\sigma_{(v_L,x^*_{v_L})}(\bar{\omega}) < \sigma_{v_L}(\bar{\omega})$. The relation between the own valuation and the players' beliefs is, however, weakened: Types $(v_H, x^*_{v_L})$ hold the same beliefs as types $(v_L, x^*_{v_H})$. Based on $\sigma_{\mathbf{h}_{i,2}}(\omega)$ we can directly determine the probability $\rho_{\mathbf{h}_{i,2}}(\mathbf{h}_{-i,2})$ that type $\mathbf{h}_{i,2} \in H_2$ assigns to her stage 2 opponent being of type $\mathbf{h}_{-i,2}$, which becomes

$$\begin{aligned}
\rho_{\mathbf{h}_{i,2}}((v_H, x^*_{v_H})) &= \sigma_{\mathbf{h}_{i,2}}(\bar{\omega})\,\pi^2_{\bar{\omega}} + (1-\sigma_{\mathbf{h}_{i,2}}(\bar{\omega}))\pi^2_{\underline{\omega}}, \qquad (41)\\
\rho_{\mathbf{h}_{i,2}}((v_H, x^*_{v_L})) &= \rho_{\mathbf{h}_{i,2}}((v_L, x^*_{v_H})) = \sigma_{\mathbf{h}_{i,2}}(\bar{\omega})\,\pi_{\bar{\omega}}(1-\pi_{\bar{\omega}}) + (1-\sigma_{\mathbf{h}_{i,2}}(\bar{\omega}))\pi_{\underline{\omega}}(1-\pi_{\underline{\omega}}),\\
\rho_{\mathbf{h}_{i,2}}((v_L, x^*_{v_L})) &= \sigma_{\mathbf{h}_{i,2}}(\bar{\omega})\,(1-\pi_{\bar{\omega}})^2 + (1-\sigma_{\mathbf{h}_{i,2}}(\bar{\omega}))(1-\pi_{\underline{\omega}})^2.
\end{aligned}$$

With $\pi_{\bar{\omega}} = 1/2 + d$, $\pi_{\underline{\omega}} = 1/2 - d$ and $\sigma_{\mathbf{h}_{i,2}}(\bar{\omega})$ given above, we obtain

$$\begin{aligned}
\rho_{(v_H,x^*_{v_H})}\left((v_H, x^*_{v_H})\right) &= \rho_{(v_L,x^*_{v_L})}\left((v_L, x^*_{v_L})\right) = \frac{1}{4} + \frac{5+4d^2}{1+4d^2}d^2,\\
\rho_{(v_H,x^*_{v_H})}\left((v_L, x^*_{v_L})\right) &= \rho_{(v_L,x^*_{v_L})}\left((v_H, x^*_{v_H})\right) = \frac{1}{4} - \frac{3-4d^2}{1+4d^2}d^2,\\
\rho_{\mathbf{h}_{i,2}}\left((v_H, x^*_{v_H})\right) &= \rho_{\mathbf{h}_{i,2}}\left((v_L, x^*_{v_L})\right) = \frac{1}{4} + d^2 \quad \text{for } \mathbf{h}_{i,2} \in \left\{(v_H, x^*_{v_L}), (v_L, x^*_{v_H})\right\},\\
\rho_{\mathbf{h}_{i,2}}\left((v_H, x^*_{v_L})\right) &= \rho_{\mathbf{h}_{i,2}}\left((v_L, x^*_{v_H})\right) = \frac{1}{4} - d^2 \quad \text{for all } \mathbf{h}_{i,2} \in H_2. \qquad (42)
\end{aligned}$$

[45] This result follows similar as in (22) and (24), replacing the prior beliefs 1/2 by $\sigma_{\mathbf{h}_{i,1}}(\bar{\omega})$.

All types $\mathbf{h}_{i,2} \in H_2$ assign identical probabilities to their opponent being of type $\mathbf{h}_{-i,2} \in \{(v_H, x^*_{v_L}), (v_L, x^*_{v_H})\}$. The only difference in beliefs about the type distribution occurs with respect to the shares of types $(v_H, x^*_{v_H})$ and $(v_L, x^*_{v_L})$.

In the equilibrium of stage 2, different types hold different beliefs about the type distribution but the players' expectations about each type's equilibrium effort are correct; this equilibrium effort depends on a player's valuation type and experience type. No closed form solution for the stage 2 equilibrium efforts is known to exist. Assuming that the equilibrium is interior, the following partial orderings of the stage 2 equilibrium efforts denoted by $x^*_{\mathbf{h}_{i,2}}$ and the expectations $E_{\mathbf{h}_{i,2}}(x_{-i,2})$ about the opponent's effort can be established.

Proposition 6 *Denote the equilibrium efforts in stage 2 by* $x^*_{(v_i, x^*_{v_j})}$ *and assume that* $x^*_{\mathbf{h}_{i,2}} \in (\underline{x}, \bar{x})$ *for all* $\mathbf{h}_{i,2} \in H_2$. *Then the following rankings of the stage 2 equilibrium efforts hold:*

$$x^*_{(v_H, x^*_{v_H})} > x^*_{(v_H, x^*_{v_L})} > x^*_{(v_L, x^*_{v_H})} \quad \text{and} \quad x^*_{(v_H, x^*_{v_H})} > x^*_{(v_L, x^*_{v_L})} > x^*_{(v_L, x^*_{v_H})}. \tag{43}$$

The equilibrium beliefs about the opponent's effort satisfy

$$E_{(v_H, x^*_{v_H})}(x_{-i,2}) > E_{(v_H, x^*_{v_L})}(x_{-i,2}) = E_{(v_L, x^*_{v_H})}(x_{-i,2}) > E_{(v_L, x^*_{v_L})}(x_{-i,2}). \tag{44}$$

Proof. In an interior equilibrium, the equilibrium efforts satisfy the first-order conditions

$$\sum_{\mathbf{h}_{-i,2} \in H_2} q\rho_{\mathbf{h}_{i,2}}(\mathbf{h}_{-i,2}) \frac{x^*_{\mathbf{h}_{-i,2}}}{(x^*_{\mathbf{h}_{i,2}} + x^*_{\mathbf{h}_{-i,2}})^2} v_i - 1 = 0, \;\; \mathbf{h}_{i,2} \in H_2. \tag{45}$$

Step 1: $x^*_{(v_H, x^*_{v_H})} > x^*_{(v_L, x^*_{v_L})}$. Using (45) for type $(v_H, x^*_{v_H})$ and the beliefs in (42),

$$\begin{aligned} q\rho_{(v_L, x^*_{v_L})}\left((v_L, x^*_{v_L})\right) \frac{1}{4x^*_{(v_H, x^*_{v_H})}} v_H + q\rho_{(v_L, x^*_{v_L})}\left((v_H, x^*_{v_H})\right) \frac{x^*_{(v_L, x^*_{v_L})}}{(x^*_{(v_H, x^*_{v_H})} + x^*_{(v_L, x^*_{v_L})})^2} v_H \\ + \sum_{\mathbf{h}_{-i,2} \in \{(v_H, x^*_{v_L}), (v_L, x^*_{v_H})\}} q\rho_{(v_L, x^*_{v_L})}\left(\mathbf{h}_{-i,2}\right) \frac{x^*_{\mathbf{h}_{-i,2}}}{(x^*_{(v_H, x^*_{v_H})} + x^*_{\mathbf{h}_{-i,2}})^2} v_H - 1 = 0. \end{aligned} \tag{46}$$

Suppose that $x^*_{(v_H, x^*_{v_H})} \leq x^*_{(v_L, x^*_{v_L})}$. Then, together with $v_L < v_H$, the left-hand side in (46) is strictly larger than

$$q\rho_{(v_L,x^*_{v_L})}\left((v_L,x^*_{v_L})\right)\frac{1}{4x^*_{(v_L,x^*_{v_L})}}v_L+q\rho_{(v_L,x^*_{v_L})}\left((v_H,x^*_{v_H})\right)\frac{x^*_{(v_H,x^*_{v_H})}}{(x^*_{(v_H,x^*_{v_H})}+x^*_{(v_L,x^*_{v_L})})^2}v_L$$
$$+\sum_{\mathbf{h}_{-i,2}\in\{(v_H,x^*_{v_L}),(v_L,x^*_{v_H})\}}q\rho_{(v_L,x^*_{v_L})}\left(\mathbf{h}_{-i,2}\right)\frac{x^*_{\mathbf{h}_{-i,2}}}{(x^*_{(v_L,x^*_{v_L})}+x^*_{\mathbf{h}_{-i,2}})^2}v_L-1,$$

which must be zero by optimality of $x^*_{(v_L,x^*_{v_L})}$. This establishes a contradiction.

Step 2: $x^*_{(v_H,x^*_{v_H})}>x^*_{(v_H,x^*_{v_L})}$. For the beliefs of types $(v_H,x^*_{v_H})$ and $(v_H,x^*_{v_L})$ in (42), note that $\rho_{(v_H,x^*_{v_H})}\left((v_H,x^*_{v_H})\right)-\rho_{(v_H,x^*_{v_L})}\left((v_H,x^*_{v_H})\right)=\rho_{(v_H,x^*_{v_L})}\left((v_L,x^*_{v_L})\right)-\rho_{(v_H,x^*_{v_H})}\left((v_L,x^*_{v_L})\right)$. Defining this difference by Δ, the first-order condition for type $(v_H,x^*_{v_H})$ is equivalent to

$$\sum_{\mathbf{h}_{-i,2}\in H_2}q\rho_{(v_H,x^*_{v_L})}\left(\mathbf{h}_{-i,2}\right)\frac{x^*_{\mathbf{h}_{-i,2}}}{(x^*_{(v_H,x^*_{v_H})}+x^*_{\mathbf{h}_{-i,2}})^2}v_H-1$$
$$+q\Delta\frac{x^*_{(v_H,x^*_{v_H})}}{(x^*_{(v_H,x^*_{v_H})}+x^*_{(v_H,x^*_{v_H})})^2}v_H-q\Delta\frac{x^*_{(v_L,x^*_{v_L})}}{(x^*_{(v_H,x^*_{v_H})}+x^*_{(v_L,x^*_{v_L})})^2}v_H=0. \quad (47)$$

Suppose that $x^*_{(v_H,x^*_{v_H})}\leq x^*_{(v_H,x^*_{v_L})}$. Then, using this inequality in the first term in (47) and combining the last two terms, the left-hand side in (47) is (weakly) larger than

$$\sum_{\mathbf{h}_{-i,2}\in H_2}q\rho_{(v_H,x^*_{v_L})}\left(\mathbf{h}_{-i,2}\right)\frac{x^*_{\mathbf{h}_{-i,2}}}{(x^*_{(v_H,x^*_{v_L})}+x^*_{\mathbf{h}_{-i,2}})^2}v_H-1+q\Delta\frac{(x^*_{(v_H,x^*_{v_H})}-x^*_{(v_L,x^*_{v_L})})^2}{4x^*_{(v_H,x^*_{v_H})}(x^*_{(v_H,x^*_{v_H})}+x^*_{(v_L,x^*_{v_L})})^2}v_H, \quad (48)$$

which is strictly larger than zero (using optimality of $x^*_{(v_H,x^*_{v_L})}$). This yields a contradiction.

Step 3: $x^*_{(v_L,x^*_{v_L})}>x^*_{(v_L,x^*_{v_H})}$. Using the beliefs of types $(v_L,x^*_{v_L})$ and $(v_L,x^*_{v_H})$ in (42), we get $\rho_{(v_L,x^*_{v_L})}\left((v_L,x^*_{v_L})\right)-\rho_{(v_L,x^*_{v_H})}\left((v_L,x^*_{v_L})\right)=\rho_{(v_L,x^*_{v_H})}\left((v_H,x^*_{v_H})\right)-\rho_{(v_L,x^*_{v_L})}\left((v_H,x^*_{v_H})\right)$. Denoting this difference again by Δ, a proof of $x^*_{(v_L,x^*_{v_L})}>x^*_{(v_L,x^*_{v_H})}$ follows along the same lines as in step 2.

Step 4: $x^*_{(v_H,x^*_{v_L})}>x^*_{(v_L,x^*_{v_H})}$. Note that $\rho_{(v_H,x^*_{v_L})}(\mathbf{h}_{-i,2})=\rho_{(v_L,x^*_{v_H})}(\mathbf{h}_{-i,2})$ for all $\mathbf{h}_{-i,2}\in H_2$. Since the left-hand side of (45) is strictly decreasing in $x^*_{h_{i,2}}$, $v_H>v_L$ implies that $x^*_{(v_H,x^*_{v_L})}>x^*_{(v_L,x^*_{v_H})}$ must hold in an interior equilibrium.

Altogether, the ranking of efforts in Proposition 6 follows by Steps 1 to 4. Since in equilibrium all players correctly anticipate the effort of a type $\mathbf{h}_{-i,2}\in H_2$ (the only difference between players emerges with respect to the beliefs $\rho_{\mathbf{h}_{i,2}}(\mathbf{h}_{-i,2})$), $x^*_{(v_H,x^*_{v_H})}>x^*_{(v_L,x^*_{v_L})}$ together with the beliefs in (42) implies (44). ■

In stage 2, the highest effort is chosen by types $(v_H,x^*_{v_H})$: players who care strongly about winning (have a valuation v_H) *and* have faced another strong type in stage 1. The lowest effort is chosen by low-valuation players $(v_L, x^*_{v_H})$ who faced a strong type in stage 1; compared to types $(v_L, x^*_{v_L})$, they are discouraged by their stage 1 experience. A player's expectations about the opponent's effort are still correlated with the own valuation type so that high-valuation players expect, on average, higher opponent's effort than low-valuation players, but conditional on a player's stage 1 experience this difference can disappear (compare (44)). In comparison to the efforts in stage 1, updating of beliefs can lead both to higher and to lower efforts in stage 2.

B.2 Probability weighting and escalation

A variant of the framework in Section 2.2 assumes that players have symmetric valuations of winning equal to v as in the benchmark case, but that the probability of winning enters into the objective function in a non-linear fashion, in line with theories of risk-taking with weighted probabilities (see, e.g., Quiggin 1982, Yaari 1987, and Prelec 1998).

Suppose that probabilities are weighted according to a function $w : [0,1] \to [0,1]$ where $w(0) = 0$, $w(1) = 1$, and w is continuous, strictly increasing and differentiable on $(0,1)$ and concave on some interval $(0,z)$, $z > 0$. If stage s is reached, anticipating equilibrium efforts $\check{x}_{i,s+k}$ and equilibrium win probabilities $\check{p}_{i,s+k}$ for $k = 1, ..., n-s$, player i maximizes her expected continuation payoff

$$w\left(q\frac{x_{i,s}}{x_{i,s}+x_{-i,s}} + \sum\nolimits_{k=1}^{n-s}(1-q)^k q\check{p}_{i,s+k}\right)v - x_{i,s} - \sum\nolimits_{k=1}^{n-s} w\left((1-q)^k\right)\check{x}_{i,s+k}. \tag{49}$$

Straightforward calculations using symmetry (hence, $\check{p}_{i,s+k} = 1/2$ for $k = 1, ..., n-s$) yield

$$\check{x}_{i,s} = \frac{qv}{4} w'\left(\sum\nolimits_{k=0}^{n-s}(1-q)^k \frac{q}{2}\right). \tag{50}$$

Therefore, equilibrium efforts $\check{x}_{i,s}$ are strictly increasing in s across all stages if w is strictly concave on $(0,z)$ for $z = \sum_{k=0}^{n-1}(1-q)^k q/2$.

As an example, let $v = 450$, $q = 1/3$, and $n = 5$. Using the functional form

$$w(p) = \frac{p^\beta}{\left(p^\beta + (1-p)^\beta\right)^{\frac{1}{\beta}}} \tag{51}$$

from Baharad and Nitzan (2008) and setting $\beta = 0.6$ yields equilibrium efforts $\check{x}_{i,1} = 18.327$, $\check{x}_{i,2} = 18.351$, $\check{x}_{i,3} = 18.677$, $\check{x}_{i,4} = 19.976$, and $\check{x}_{i,5} = 25.248$.

B.3 Average escalation by treatment

Indep. var.	(1) BASE	(2) EXIT	(3) EXIT ($exit_{ir1} = 0$)	(4) Pooled
	Dependent variable: individual effort x_{irs}			
Constant	42.554***	36.481***	38.002***	42.945***
	(3.614)	(9.789)	(9.918)	(3.526)
Stage_{s-1}	0.775*			1.573***
	(0.471)			(0.518)
$\mathbf{1}_{s\geq 2}$		3.720	5.020**	-3.073***
		(2.299)	(2.472)	(0.949)
EXIT				-5.503
				(7.147)
EXIT$\times\text{Stage}_{s-1}$				-1.858
				(1.396)
EXIT$\times\mathbf{1}_{s\geq 2}$				8.154**
				(3.374)
Beliefs $E_{irs}(x_{-irs})$	0.262***	0.311***	0.302***	0.271***
	(0.042)	(0.051)	(0.059)	(0.034)
Beliefs $(E_{irs}(x_{-irs}))^2$	-0.001***	-0.001	-0.000	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Round fixed effects	YES	YES	YES	YES
Session fixed effects	YES	YES	YES	YES
Socioeconomics	YES	YES	YES	YES
Observations	7946	2878	2576	10824

Note: Random-effects regressions; standard errors in parentheses, clustered at the level of matching groups; ***(**,*) significant at 1%(5%,10%). Data from rounds 6 to 15. Estimation (3): observations in stages 2 to 5 included only if subject i preferred not to exit in stage 1 of round r. "Stage_{s-1}" is equal to stage number $s-1$. $\mathbf{1}_{s\geq 2} = 1$ if stage ≥ 2, and $\mathbf{1}_{s\geq 2} = 0$ otherwise.

Table 3: Individual effort over stages 1 to 5.

B.4 Accuracy of beliefs over time

Dependent variable: belief accuracy $\frac{\lvert E_{irs}(x_{-irs})-x_{-irs}\rvert}{x_{-irs}}$				
	(1)	(2)	(3)	(4)
	BASE	BASE	BASE	EXIT
Indep. var.		(nonincentiv.)	(incentivized)	
Constant	7.332***	7.564***	9.292***	5.646***
	(1.174)	(1.556)	(2.285)	(2.104)
$\mathbf{1}_{\text{strong type}}$	3.971**	4.923*	2.510	1.846
	(1.923)	(2.554)	(2.499)	(2.752)
Stage $\text{contest}_{r\times s}$	−0.391***	−0.373**	−0.424***	−0.441***
	(0.101)	(0.147)	(0.098)	(0.136)
$\mathbf{1}_{\text{strong type}}\times$Stage $\text{contest}_{r\times s}$	−0.182	−0.271	−0.021	−0.258
	(0.146)	(0.200)	(0.190)	(0.265)
(Stage $\text{contest}_{r\times s})^2$	0.006***	0.006***	0.007***	0.008***
	(0.002)	(0.003)	(0.002)	(0.003)
$\mathbf{1}_{\text{strong type}}\times$(Stage $\text{contest}_{r\times s})^2$	0.002	0.004	−0.000	0.005
	(0.003)	(0.004)	(0.003)	(0.005)
Round fixed effects	NO	NO	NO	NO
Session fixed effects	YES	YES	YES	YES
Socioeconomics	YES	YES	YES	YES
Observations	12056	7832	4224	4328

Note: Random-effects regressions; standard errors in parentheses, clustered at the level of matching groups; ***(**,*) significant at 1%(5%,10%). Data from rounds 1 to 15. Estimation (2): data from sessions of the BASE treatment in which belief elicitation was not incentivized; estimation (3): data from sessions of the BASE treatment in which belief elicitation was incentivized. Dependent variable is the absolute value of the difference of stated beliefs and actual opponent's effort, divided by opponent's effort. $\mathbf{1}_{\text{strong type}} = 1$ if subject i's average effort in rounds 1 to 5 higher than average effort of all subjects in rounds 1 to 5 of the respective treatment, and $\mathbf{1}_{\text{strong type}} = 0$ otherwise. "Stage $\text{contest}_{r\times s}$" is the number of the stage contest played (from 1 to 44).

Table 4: Updating of beliefs: Belief accuracy over the stage contests played.

B.5 Accuracy of beliefs with and without monetary incentives

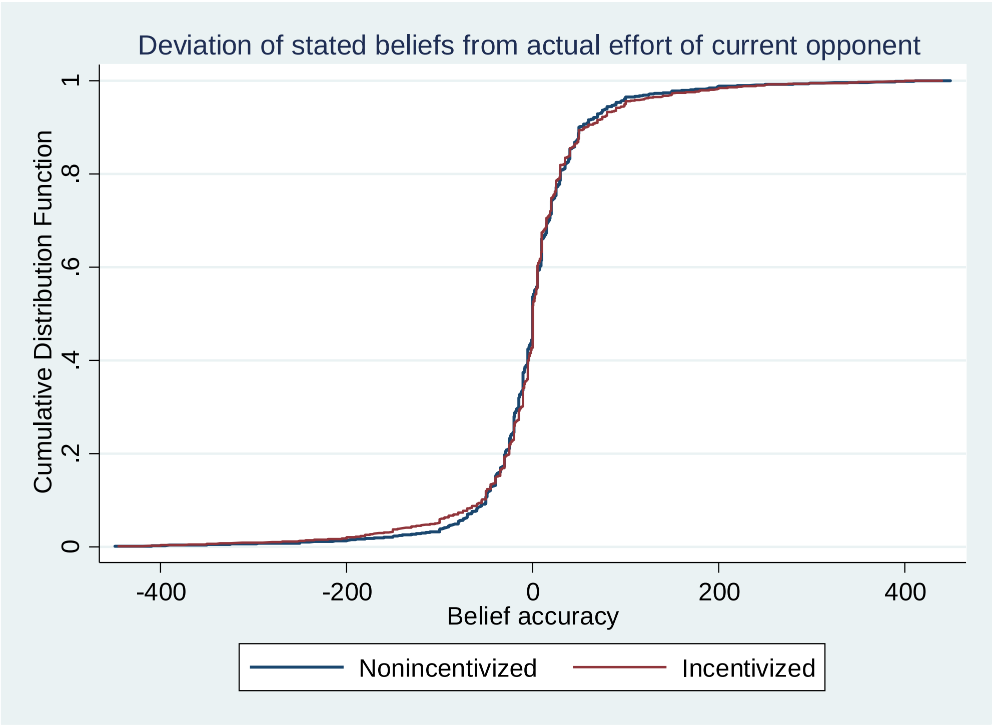

Figure 3: Difference of stated beliefs and opponent effort ($E_{irs}(x_{-irs}) - x_{-irs}$) in the BASE treatment, separately for the sessions with and without monetary incentives for correct beliefs.

B.6 Stated beliefs across the stages

	Dependent variable: beliefs $E_{irs}(x_{-irs})$			
	(1)	(2)	(3)	(4)
	BASE	BASE	BASE	EXIT
Indep. var.		(Early rounds)	(Late rounds)	
Constant	36.110***	46.207***	36.303***	28.414**
	(3.777)	(6.352)	(3.921)	(11.220)
$\mathbf{1}_{\text{strong type}}$	8.731**	26.500***	8.087**	3.387
	(3.620)	(3.877)	(3.733)	(6.343)
Stage_{s-1}	0.372	−5.517***	0.663	
	(0.698)	(0.770)	(0.856)	
$\mathbf{1}_{\text{strong type}} \times \text{Stage}_{s-1}$	−2.369**	−3.207**	−2.673**	
	(1.097)	(1.338)	(1.272)	
$\mathbf{1}_{s \geq 2}$				2.131
				(3.666)
$\mathbf{1}_{\text{strong type}} \times \mathbf{1}_{s \geq 2}$				−3.371
				(6.177)
$-i$'s effort x_{-ir1}	0.070***	0.122***	0.047**	0.090***
	(0.020)	(0.020)	(0.019)	(0.019)
Round dummies	YES	YES	YES	YES
Session fixed effects	YES	YES	YES	YES
Socioeconomics	YES	YES	YES	YES
Observations	7946	6302	5754	2878

Note: Random-effects regressions; standard errors in parentheses, clustered at the level of matching groups; ***(**,*) significant at 1%(5%,10%). Estimations (1) and (4): data from rounds 6 to 15; estimation (2): data from early rounds (rounds 1 to 7); estimation (3): data from late rounds (rounds 8 to 15). $\mathbf{1}_{\text{strong type}} = 1$ if subject i's average effort in rounds 1 to 5 higher than average effort of all subjects in rounds 1 to 5 of the respective treatment, and $\mathbf{1}_{\text{strong type}} = 0$ otherwise. "Stage_{s-1}" is equal to stage number $s-1$. $\mathbf{1}_{s \geq 2} = 1$ if stage ≥ 2, and $\mathbf{1}_{s \geq 2} = 0$ otherwise.

Table 5: Updating of beliefs over stages 1 to 5: Strong vs. weak types.

B.7 Effort dynamics depending on the share of strong types

Indep. var.	(1) BASE (Many weak types)	(2) BASE (Many strong types)	(3) BASE	(4) BASE
	Dependent variable: individual effort x_{irs} in BASE			
Constant	27.204***	32.341***	30.569***	24.893***
	(2.835)	(6.225)	(4.280)	(4.791)
$\mathbf{1}_{\text{strong type}}$	23.075***	21.880***	23.325***	25.189***
	(4.694)	(3.815)	(6.424)	(6.936)
Stage_{s-1}	1.781***	0.852	1.890**	2.158**
	(0.490)	(0.876)	(0.750)	(0.865)
$\mathbf{1}_{\text{strong type}} \times \text{Stage}_{s-1}$	−2.193	−1.131	−3.101	−3.395
	(1.827)	(1.121)	(2.539)	(2.696)
ShareStrong_g			1.217	8.637
			(6.342)	(7.794)
$\mathbf{1}_{\text{strong type}} \times \text{ShareStrong}_g$			−2.294	−5.404
			(12.817)	(13.823)
$\text{Stage}_{s-1} \times \text{ShareStrong}_g$			−1.100	−2.243
			(2.134)	(2.464)
$\mathbf{1}_{\text{strong type}} \times \text{Stage}_{s-1}$ $\times \text{ShareStrong}_g$			2.787	3.356
			(4.454)	(4.801)
Beliefs $E_{irs}(x_{-irs})$	0.276***	0.235***	0.259***	
	(0.036)	(0.062)	(0.042)	
Beliefs $(E_{irs}(x_{-irs}))^2$	−0.001***	−0.001***	−0.001***	
	(0.000)	(0.000)	(0.000)	
Round dummies	YES	YES	YES	YES
Session fixed effects	YES	YES	YES	YES
Socioeconomics	YES	YES	YES	YES
Observations	4176	3770	7946	7946

Note: Random-effects regressions; standard errors in parentheses, clustered at the level of matching groups; ***(**,*) significant at 1%(5%,10%). Data from rounds 6 to 15. $\mathbf{1}_{\text{strong type}} = 1$ if subject i's average effort in rounds 1 to 5 higher than average effort of all subjects in rounds 1 to 5 of the respective treatment, and $\mathbf{1}_{\text{strong type}} = 0$ otherwise. "Stage_{s-1}" is equal to stage number $s-1$. "ShareStrong_g" is the share of subjects in group g classified as 'strong type.' Estimation (1): data from matching groups with less than 50% of strong types only; estimation (2): data from matching groups with 50% or more strong types only.

Table 6: Efforts over stages 1 to 5, depending on the share of strong types in the population.

B.8 Efforts and beliefs with fixed matching

Dependent variable:	effort x_{irs}	effort x_{irs}	beliefs $E_{irs}(x_{-irs})$
	(1)	(2)	(3)
Indep. var.	FIXED	FIXED	FIXED
Constant	29.308***	19.285***	21.117***
	(5.389)	(4.971)	(3.805)
$\mathbf{1}_{\text{strong type}}$		23.953***	17.425***
		(5.495)	(2.924)
Stage_{s-1}	1.019*	2.410***	−0.577
	(0.558)	(0.392)	(0.970)
$\mathbf{1}_{\text{strong type}} \times \text{Stage}_{s-1}$		−3.725**	−0.478
		(1.714)	(1.650)
$-i$'s effort x_{-ir1}	0.032**	0.030**	0.149***
	(0.014)	(0.014)	(0.049)
Beliefs $E_{irs}(x_{-irs})$	0.304***	0.297***	
	(0.054)	(0.057)	
Beliefs $(E_{irs}(x_{-irs}))^2$	−0.001**	−0.001**	
	(0.000)	(0.000)	
Round dummies	YES	YES	YES
Session fixed effects	YES	YES	YES
Socioeconomics	YES	YES	YES
Observations	2784	2784	2784

Note: Random-effects regressions; standard errors in parentheses, clustered at the level of matching groups; ***(**,*) significant at 1%(5%,10%). Data from rounds 6 to 15. $\mathbf{1}_{\text{strong type}} = 1$ if subject i's average effort in rounds 1 to 5 higher than average effort of all subjects in rounds 1 to 5 of the respective treatment, and $\mathbf{1}_{\text{strong type}} = 0$ otherwise. "Stage_{s-1}" is equal to stage number $s-1$.

Table 7: Efforts and beliefs over stages 1 to 5: Treatment with fixed matching of opponents.

As the only modification of the FIXED treatment compared to BASE, the subjects are randomly matched in pairs and remain in the same pair for the (up to) five stages. Between the rounds, the subjects are randomly re-matched.

C Experimental instructions (translated from German)

C.1 Instructions for the BASE treatment

Welcome to this experiment! Please read the following instructions carefully and completely. A full understanding of them might help you to earn more money.

Your earnings in this experiment will be measured in Talers. At the end of the experiment the Talers which you have earned after subtracting your investments will be converted to cash and paid to you by the laboratory. For every 50 Talers you earn you will be paid 1 euro in cash. In addition, each participant will receive a show-up-fee of 6 euros.

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

Your task In the main part of today's experiment, pairs of two participants will decide about the allocation of 450 Talers. The allocation of the 450 Talers within a pair of participants takes place as follows:

1. Each of the two participants expends an amount of Talers. To do so, you will simultaneously and independently choose any positive integer between 1 and 450 as your amount of Talers. Each participant has to pay his expenditure (in Talers), independent of the further progress of the experiment.

2. In addition, both participants will be asked to provide an estimate of how much the other participant within their pair expends. For this purpose, you will choose a number between 1 and 450. Your estimation will not be communicated to the other participant.

3. Afterwards, you will be shown on the screen how many Talers you and the other participant in your group have expended.

4. The allocation of the 450 Talers will be decided by a "wheel of fortune," which is divided into three segments. One segment covers two thirds of the wheel's area and is marked in gray. This segment represents the probability that neither of the participants within the pair receives the 450 Talers. Thus, the probability that neither of the two participants receives the 450 Talers in the respective rotation of the wheel is equal to two-thirds, independent of the expenditures chosen by the two participants.

The remaining one-third of the wheel's area is divided into a blue and a red segment. On your screen, the blue segment represents the probability that you will receive the 450 Talers, and the red segment represents the probability that the other participant in your pair will receive the 450

Talers. The ratio of the blue and the red segment exactly matches the ratio of the expenditures of the two participants. Your (blue) segment is larger, the higher your own expenditure and the lower the other participant's expenditure.

The following table shows the resulting probabilities for the allocation of the 450 Talers to you, to the other participant in your pair, or for the case that neither of you receives the 450 Talers.

	The 450 Talers are not allocated	You receive the 450 Talers	The other participant receives the 450 Talers
Probability:	2/3	$\frac{1}{3} * \frac{\text{Your expenditure}}{\text{Your expenditure + Other's expenditure}}$	$\frac{1}{3} * \frac{\text{Other participant's expenditure}}{\text{Your expenditure + Other's expenditure}}$
Colored in:	Gray	Blue	Red

To summarize: If you choose a higher amount of Talers as your expenditure, the probability that you receive the 450 Talers is higher, but the amount you have to pay as the costs of your expenditure is higher as well.

In the experiment, when deciding on your expenditure, you will have the possibility to calculate the allocation probabilities for possible expenditures of both participants by using an on-screen calculator.

5. Shortly after the choice of the expenditures, the arrow of the "wheel of fortune" will start rotating and will randomly stop at one of the three segments.

- If the arrow stops in the blue segment, you receive the 450 Talers and the round ends.
- If the arrow stops in the red segment, the other participant in your pair receives the 450 Talers and the round ends.
- If the arrow stops in the gray segment, neither you nor the other participant will receive the 450 Talers. Instead, the decision on the allocation of the 450 Talers will start anew. This means that you will once again choose your expenditures, as outlined above from step 1 onwards, and there will be another rotation of the wheel of fortune.

Please note:

- The round ends after five iterations at the latest if the 450 Talers have not been allocated to either you or to the other participant by then. This is the case if the wheel's arrow stops in the gray segment in five subsequent iterations. In that case, the 450 Talers will not be allocated in this round to either participant within the pair.
- You will choose an expenditure in each of the up to five iterations. You will have to pay the cost of your expenditure in each iteration, whether you receive the 450 Talers, the other participant receives the 450 Talers, or the 450 Talers are not allocated.

If the arrow stops in the gray segment and the allocation of the 450 Talers will be determined in a new iteration, new groups of participants will be formed by the laboratory. Hence, the participant you face within your pair will be newly and randomly assigned to you.

The procedure The main part of the experiment consists of 15 identical and independent rounds. In each of these rounds, expenditures will be chosen and the allocation of 450 Talers among two participants will be decided according to the rules outlined above, in potentially up to five iterations.

The pairs of participants will be randomly formed by the laboratory in every round so that you will typically face new participants in every round. You will not know who the respective other participant in your group is. Every attempt to reveal your identity will result in an exclusion from the experiment.

Also within one round, the composition of the pairs of participants will be randomly determined in each iteration. Hence, also within one round you will typically face different participants in the different iterations.

At the end of today's experiment, the Talers that you have received in 3 out of the 15 rounds will be added up and the costs for the Talers that you may have expended in these three rounds will be subtracted.[46] The resulting amount of Talers will be converted to Euros (50 Talers = 1 euro). The expenditures and Talers received in all the remaining rounds will not be considered for your final earnings. Therefore, for these remaining rounds, you will neither receive possible gains nor will you have to pay the cost of any expenditures. Which 3 out of the 15 rounds are selected to determine your earnings will be determined randomly at the end of the experiment.

Furthermore, you will receive 10 euros, which are being added to your earnings (gain or loss) from the three randomly determined rounds. On top of that, you will receive a show-up fee of 6 euros. The resulting amount of money will be paid to you in cash.

Before the experiment shortly starts, some questions regarding the procedure of the experiment will appear on your computer screen. These questions are supposed to illustrate the rules of the experiment. Moreover, we will ask you to answer some further questions after the main part of the experiment is over. Of course, your decisions during the main part of the experiment and your answers to these questions are only being used in an anonymized way.

Thank you very much for participating in this experiment and good luck.

[46] In the sessions in which belief elicitation was incentivized, the following text was inserted:

"For one further round, you receive 450 Talers if your estimate of the other participant's expenditures (compare step 2 above) was sufficiently accurate. More precisely, you receive 450 Talers if your estimates in the selected round deviated, on average, no more than 5 Talers from the expenditures of the respective other participants."

In addition, in the last sentence of this paragraph, "3 out of 15" was replaced by "in total 4 out of 15" as to include the round for which accurate beliefs were rewarded.

C.2 Modifications of the instructions for the EXIT treatment[47]

6. If the 450 Talers are not allocated in the first iteration, you can make a choice about whether to continue the round with further iterations. On the screen, two options will be shown. One option is to "CONTINUE," the other option is to "EXIT." You and the other participant within your group decide whether you would like to continue the round with further iterations or end the round, by independently choosing one of the two options.

- If both of you choose "CONTINUE" then the decision on the allocation of the 450 Talers will start anew. This means that you will again choose expenditures, as outlined in steps 1 to 5 above, and there will be another rotation of the wheel of fortune.
- If both of you choose "EXIT" then each of you will receive a payment of 60 Talers. The amount of 450 Talers will, however, not be allocated.

If you and the other participant choose different options, a coin flip will decide whether the decision on the allocation of the 450 Talers will start anew or whether the allocation will end with a payment of 60 Talers as just described.

Please note:

- The round ends after five iterations at the latest if the 450 Talers have not been allocated to either you or to the other participant by then. This is the case if the wheel's arrow stops in the gray segment in five subsequent iterations. In that case, the 450 Talers are not allocated to either participant within the pair in this round.
- You choose an expenditure in each of the up to five iterations. You have to pay the cost of your expenditure in each iteration, whether you receive the 450 Talers, the other participant receives the 450 Talers, or the 450 Talers are not allocated.
- If the 450 Talers have not been allocated in the first iteration, you can decide whether you would like to continue this round. This option will only be available at the end of the first iteration and will not be available after possible further iterations.

[47] For the instructions of the EXIT treatment, the additional step 6 is inserted after step 5 of the description of the task in BASE above.

References

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[4] Yaari, Menahem E., 1987, The dual theory of choice under risk, Econometrica, 55(1), 95-115.