The Parasite Game: Exploiting the Abundance of Nature in Face of Competition

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May 21, 2001

Abstract

A situation in which the regularity in nature can be utilized while competition is to be avoided is modelled by the Parasite game. In this game regular behavior could enhance guessing nature but strategic randomization is required to avoid being outguessed. In an experiment, 60 pairs of participants (partner design) played many rounds of the Parasite game. The treatments differed in nature's probabilities and whether or not these probabilities were announced in advance or could only be experienced over time. Before playing, the working memory (WM) of participants was measured. Data analyses test the correspondence of participants behavior to game-theoretic benchmarks and the effect of participants' WM on their behavior.

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1 Introduction

It is not uncommon that natural resources are more abundant in one location than in another. For example, fish may be more abundant in one lake than in another, nectar may be found with a higher probability in one field than in another and there may be a higher chance of hitting a gold ore on one side of the mountain than in another. An organism seeking these resources would be wise to always choose the more abundant location over the other.

However, if a second organism, parasitic on the first, is also frequenting the same locations – robbing whatever the first organism has managed to collect – choice between the two locations becomes more complicated for both organisms. Had the first organism continued to always choose the better location, the second organism would take advantage of that regularity and always manage to rob the resources away. Clearly, regular behavior on the part of either organism would be easily exploited by the other. What would each of the two organisms choose?

To model the situation we have devised a game which we call "the Parasite Game", and have collected experimental data from 60 pairs of participants. Theoretical analysis and data analysis may shed light on the strategies adopted by participants in each role.

In the following we first introduce the "Parasite game" (section 2) before analyzing its benchmark solutions and the hypotheses they suggest (section 3). After describing the experimental procedure (section 4) we present and statistically analyze the experimentally observed behavior (section 5). Section 6 concludes.

2 The Parasite game

The Parasite game involves two players and an indifferent 'nature'. The game is represented in extensive form in Figure II.1 (where the two players are named player 1 and 2 and nature the chance player 0) and as a 2×2-bimatrix game in Table II.2. As usual in evolutionary game theory the notation of moves is not arbitrary but meaningful. H and T stand for two different locations where by nature's choice between H and T a resource for player 1 becomes available. Thus H and T are also the locations where player 1 can search for the resource and where finally player 2 can try to get hold of player 1. Our interpretation of player 2 is that of a parasite who, rather than search for the resource by itself profits by robbing it from player 1 whenever player 1 has suceeded in producing. Of course, one might see player 2 also as a predator and player 1 as his potential prey whose hunt is only promising if the prey is well fed.[1]

Nature's probability w for location H is assumed (without loss of generality) to be at least as large as the probability $1 - w$ for T, i.e. $w \geq 1/2$. Success of player 1 means to guess nature but not to be outguessed by player 2. For player 2 it means to outguess player 1 when player 1 has guessed nature. Success is evaluated with payoff level 1 whereas all cases of non-success yield the payoff level 0. Although the game is very competitive (only one player can be successful), it is not a constant sum game since for $w > 1/2$ the probability that at least one player is successful is more promising at location H. Furthermore, irrespective of w it is possible that no player at all is successful (when 1 misses nature's move).

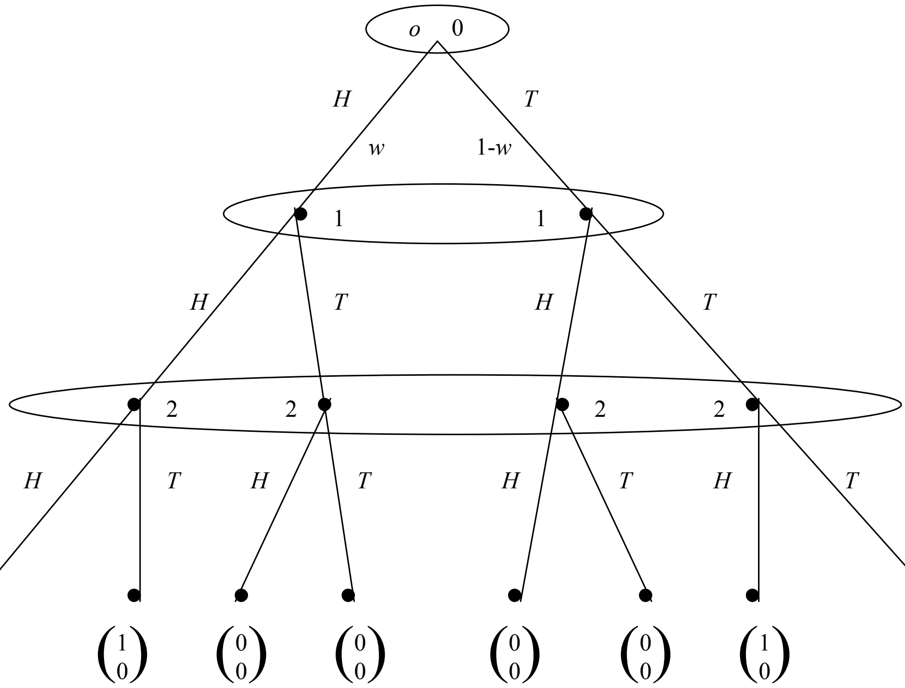

Figure II.1: Parasite game in extensive form (o is the origin where the game starts with

[1] In homo sapiens player 1 could be a gold digger whose nuggets the gangster (player 2) wants to steal.

nature 0's move; payoffs for players 1 and 2 are given in the natural order; nature's probability for H is w and $1-w$ for T)

pl. 2 / pl. 1	H	T
H	$0,\ w$	$w,\ 0$
T	$1-w,\ 0$	$0,\ 1-w$

Table II.2: The Parasite game as a 2×2-bimatrix game (payoff expectations for each cell are given in the natural order)

In the model at hand nature provides all what is available. Other models (e.g. Grossman and Kim, 1995) assume that what becomes available has to be produced. More specifically, the game model of Grossman and Kim assumes that player 1 (2) can allocate the available endowment of resources to production purposes or investment in defense (attack) capability. Unlike in our model there is no uncertainty. Rather one needs technological relationships prescribing how output depends on productions efforts and how much of player 1's output can be appropriated by player 2 for given investments in defense, respectively attack. An experimental study (Carter and Anderton, 2001) claims clear evidence that with experience behavior converges to (subgame perfect) equilibrium behavior.

3 Benchmark solutions

From Table II.2 it is obvious that the game has no pure strategy equilibrium from which no single player can deviate profitably: If players 1 and 2 are at the same location, player 1 would gain by deviating, which, in turn, could cause player 2 to do so. The only completely mixed strategy equilibrium predicts[2] that player 1 uses H with probability $1-w$ and player 2 with probability w, i.e. both players react to the probability w in

[2] If s_i denotes i's probability for H and $U_i(s_i, s_j)$ the utility of i when i plays s_i and j with $j \neq i$ the strategy s_j, an equilibrium $s^* = (s_1^*, s_2^*)$ requires $\frac{\partial}{\partial s_i} U_i\left(s_i^*, s_j^*\right) \geq 0$ when $s_i^* = 1$, ≤ 0 when $s_i^* = 0$, and $= 0$ when $s_i^* \in (0,1)$ for $i = 1, 2$. Thus $(s_1^*, s_2^*) \in (0,1)^2$ requires $w(1-s_2^*) = (1-w)s_2^*$ and $ws_1^* = (1-w)(1-s_1^*)$ and thus $(s_1^*, s_2^*) = (1-w, w)$.

nature by either using H with its complementary probability (player 1) or by probability matching (player 2).

Let us now abstract from rationality in the sense of marginal calculus. In strategy settings the concept of an impulse balance equilibrium (Selten, Abbink, and Cox, 2001) focuses on overall payoff implications rather than on marginal effects. It assumes that what drives individual behavior is (expected) regret[3] rather than (expected) payoff.

For any given strategy vector $s = (s_1, s_2) \in [0,1]^2$ expected regret of both players is balanced when $(1-w)\, s_1 s_2 = w\,(1-s_1)\,(1-s_2)$ and $w s_1\,(1-s_2) = (1-w)\,(1-s_1)\, s_2$ so that $s_1 = 1/2$ and $s_2 = w$ must hold.

Hypothesis 1:

(i) Both players react, albeit in opposite ways, to changes of w.

(ii) Player 2 will be more reactive to w than player 1, e.g. in the sense that player 2's probability of using H is close to w.

Part (i) of Hypothesis 1 is suggested by the equilibrium solution $s^* = (s_1^*, s_2^*)$ with $s_1^* = 1-w$ and $s_2^* = w$ whereas part (ii) follows from impulse balancing.

It is interesting that introducing social preferences[4] in the sense of

- altruism (if u_i for $i = 1,2$ denotes player i's payoff, i's utility $U_i = u_i + \alpha_i u_j$ for $j \neq i$ with $0 < \alpha_i < 1$ depends on u_i and u_j) or
- inequality aversion ($U_i = u_i - \beta_i \max\{0, u_i - u_j\}$ for $i = 1,2$ and $j \neq i$ with $\beta_i > 0$)
- envy ($U_i = u_i - \gamma_i \max\{0, u_j - u_i\}$ for $i = 1,2$ and $j \neq i$ with $\gamma_i > 0$)

[3] Expected regret will, of course, hardly ever be experienced by participants who might try to balance experienced regret from either choice. For a benchmark such path dependence is, however, unwarranted, especially since it implies heterogeneity in behavior due to individual variation in past experiences.

[4] Social preferences are frequently employed when trying to account for experimental results, e.g. Bolton (1991), Bolton and Ockenfels (2000), Fehr and Schmidt (1999), Kirchsteiger (1994), Pearce, Stacchetti, Geanakoplos (1989), Rabin (1993).

would not affect player 1's behavior at all.[5] All that altruism (in the sense of $1 > \alpha_1 > 0$) brings about is that player 2 uses H with probability larger than w. Similarly inequality aversion (in the sense of $\beta_1 > 0$) or envy (in the sense of $\gamma_1 > 0$) causes player 2 to choose H with probability smaller than w. In view of these results we will be interested in testing

Hypothesis 2:

(i) $s_1 + s_2 = 1$ (where the observation s_i is the average probability of H by participants in the role of player $i = 1, 2$),

(ii) $s_1 + s_2 > 1$ if $w > 1/2$,

(iii) $s_1 + s_2 < 1$ if $w > 1/2$,

In Hypothesis 2 we thus allow for opportunism (part (i) where $U_i = u_i$ for $i = 1, 2$ is assumed), for altruism leading to $s_1 + s_2 > 1$ (part (ii)) and inequality aversion or envy with $s_1 + s_2 < 1$ (part (iii)) for $w > 1/2$. Common to all these specific predictions is that whatever motivates a player is commonly known and that both players are (commonly known to be) rational. Furthermore, it has been implicitly assumed[6] that α_1 and β_1 are sufficiently small to guarantee $s_2^* \in (0, 1)$.

If for $w > \frac{1}{2}$ one is only interested in the sum of expected payoffs ($U_i = u_1 + u_2$ for $i = 1, 2$) player 1 would have to choose H always.[7] The sum $u_1 + u_2 = w$, implied by $s_1 = 1$, could be allocated then in any desired proportion s_2 for player 2 and $1 - s_2$ for player 1 by player 2's strategy $s_2 \in [0, 1]$.

Hypothesis 3:

[5] Proceeding as in footnote 1 yields $s_1^* = 1 - w$ always and $s_2^* = s_2^*(\alpha_1) = [(1 + \alpha_1) w - \alpha_1] / (1 - \alpha_1)$ with $s_2^*(\alpha_1) \geq w$, $s_2^* = s_2^*(\beta_1) = [\beta_1 (1 - w) + w] / (1 + \beta_1)$ with $s_2^*(\beta_1) \leq w$ and $s_2^* = s_2^*(\gamma_1) = [w + (1 - w)\gamma_1] / (1 + \gamma_1)$ with $s_2^*(\gamma_1) \leq w$ due to $w \geq 1/2$ and $s_2^*(\alpha_1) \longrightarrow w\,(\alpha_1 \longrightarrow 0)$, $s_2^*(\beta_1) \longrightarrow w\,(\beta_1 \longrightarrow 0)$, $s_2^*(\gamma_1) \longrightarrow w\,(\gamma_1 \longrightarrow 0)$.

[6] If $s_2^* \notin (0, 1)$ player 1's strategy s_1^* does not any longer have to satisfy $s_1^* = 1 - w$: To $\alpha_1 > 0$ leading to $s_2^*(\alpha_1) = 1$ player 1 can react by $s_1^* = 1$ if $w > 1/(1 + \alpha_1)$ whereas for all $\beta_1 \geq 0$ one always has $s_2^*(\beta_1) \in (0, 1)$.

[7] The obvious idea to study this case as a limit case of altruism in the sense of $\alpha_1 = 1 = \alpha_2$ would yield the same result where one, however, cannot rely on the solution for an interior equilibrium, derived above, since $s_2^*(\alpha_1)$ is not well-defined for $\alpha_1 = 1$. If $\alpha_1 = 1$ the condition that H is better than T for player 1 is equivalent to $w > 1/2$.

(i) $s_1(w) > 1 - w$ for $w > 1/2$ and
$s_1(\overline{w}) > s_1(\underline{w})$ for $\overline{w} > \underline{w} \geq 1/2$,

(ii) $s_2(s_1)$ decreases with s_1.

Part (i) of Hypothesis 3 expresses the concern for efficiency in the sense of $U_i = u_1 + u_2$ where it seems natural to conjecture that this concern is positively related to the profitability of cooperation as measured by w ($> 1/2$). Part (ii) is motivated by reciprocity considerations. If player 2 observes that player 1 cares a lot for efficiency (by often choosing H, i.e. by relying on a rather large s_1), he should reward him by decreasing s_2 instead of discouraging him (by exploiting him via $s_2 = 1$).

Our hypotheses so far are rather general. One may, of course, have tried to elicit player 1's (degree of) opportunism, altruism (α_1), inequality aversion (β_1) or envy (γ_1) in order to account for individual differences in behavior.[8] However, we have preferred to let a pair of participants play the same game very often (partner design) and to detect differences in individuals or in pairs of participants by analyzing their sequences of play. Thus instead of estimating altruism (α_1), inequality aversion (β_1) or envy (γ_1) independently one can simply classify pairs of participants according to their average sum $s_1 + s_2$ of H-shares like in Hypothesis 2. One, furthermore, can explore whether and how experienced behavior differs from initial behavior etc. Hypotheses by which we will try to account for heterogeneity in individuals and in pairs of participants will be introduced before testing them.

The benchmark solutions considered typically call for mixed strategies. It is known that people's working memory (WM) capacity - which determines the number of items they can process simultaneously - is related to their systematic deviations from randomness (Kareev, 1992; Rapoport and Budescu, 1997) in individual settings. Since characteristics of WM affect individual behavior in individual settings, characteristics of both players might be related also to the emergent interaction between them. We therefore measured the WM capacity of every player and explored its relationship to the behavior observed.

[8] Although the benchmark solutions do not suggest any relevance of player 2's inclinations, one could, of course, be interested in them, too.

4 Experimental procedure

The experiment employs the 3×2-factorial design in Table IV.1. It is based on three probabilities $w \geq 1/2$, namely $1/2$, $2/3$, and $3/4$. The probability w is either commonly known before starting the first play, or can be only experienced over time. We refer by K(nown) to sessions where w was known and by $K(w)$ to the such a session with parameter w. Similarly, U(nknown) and $U(w)$ indicates sessions where w was unknown initially.

w / information about w	1/2	2/3	3/4
U	$U(1/2)$	$U(2/3)$	$U(3/4)$
K	$K(1/2)$	$K(2/3)$	$K(3/4)$

Table IV.1: The 2×3-factorial design (K (U) $- w$ is commonly (un)known)

More details of the experimental procedure are obvious from the experimental protocol (Appendix A) and from (an English translation of) the instructions (Appendix B). After being subjected, individually, to a standard digit-span test a pair of participants was randomly assigned to the role of players 1 and 2, and played together (partner design) around 100 successive rounds of the Parasite game with immediate feedback about past play after each round. The average time needed was 25 minutes and the average earning 50 NIS (approx. 12.5 Euro at the time of the experiment).

An overview what the three benchmark solutions, derived above, imply in terms of behavior (s_1 and s_2), of individual payoffs (u_1 and u_2) as well as of overall efficiency ($u_1 + u_2$), is provided by Table IV.2. It reminds of the general solution and lists the numerical results for $w = 1/2$, $2/3$ and $3/4$. It again illustrates that naturally (Pareto-)efficiency is socially optimal, that according to the impulse balance equilibrium efficiency is insensitive to w whereas efficiency declines with larger probability $w \geq 1/2$ according to the unique (Nash-)equilibrium.

concept	w	s_1	s_2	u_1	u_2	$u_1 + u_2$
	general	$1-w$	w	$w(1-w)$	$w(1-w)$	$2w(1-w)$
equilibrium	1/2	1/2	1/2	25	25	50
	2/3	1/3	2/3	22.2	22.2	44.4
	3/4	1/4	3/4	18.7	18.7	37.4
	general	1/2	w	$w(1-w)$	$1/2 - w(1-w)$	1/2
impulse	1/2	1/2	1/2	25	25	50
balance	2/3	1/2	2/3	22.2	27.8	50
	3/4	1/2	3/4	18.7	31.3	50
	general	1	1/2	$w/2$	$w/2$	w
efficiency	1/2	1	1/2	25	25	50
	2/3	1	1/2	33.3	33.3	66.6
	3/4	1	1/2	37.5	37.5	75

Table IV.2: The benchmark behavior and payoffs for the unique (Nash-)equilibrium, the impulse balance equilibrium and for (Pareto-)efficiency

The altogether 60 participants were allotted to the different conditions as follows: 12 to $w = 1/2$ and 24 to $w = 2/3$ and 3/4, respectively. In each group half of the pairs were in the known and the other half in the unknown condition.

5 Results

We can now attempt to answer the question posed in the introduction as to what each of the organisms in the situation would choose to do.

To ignore beginning and end effects the first and last few rounds are excluded from analysis and only rounds 6 to 95 are reported. These are divided into three periods: 1-early (rounds 6-35), 2-middle (rounds 36-65) and 3-late (rounds 66-95). Table V.1 provides a rough overview with the average results of s_1, s_2, u_1, u_2 and $u_1 + u_2$ separately for each of the three periods and separately for the Known and Unknown treatment.

	PROB	KNOWL	s_1	s_2	u_1	u_2	$u_1 + u_2$
Period 1	.50	.00	.50	.52	6.72	6.87	13.59
		1.00	.49	.43	7.17	7.33	14.50
	.67	.00	.50	.57	6.58	8.89	15.46
		1.00	.57	.63	7.42	8.58	16.00
	.75	.00	.52	.55	7.00	8.42	15.42
		1.00	.50	.72	5.33	9.42	14.75
	Total	.00	.51	.55	6.77	8.30	15.07
		1.00	.53	.63	6.53	8.67	15.20
period 2	.50	.00	.49	.52	8.00	7.67	15.67
		1.00	.46	.47	6.00	7.33	13.33
	.67	.00	.49	.57	6.83	8.25	15.08
		1.00	.50	.67	7.50	7.75	15.25
	.75	.00	.49	.57	7.42	7.58	15.00
		1.00	.42	.79	5.33	8.33	13.67
	Total	.00	.49	.56	7.30	7.87	15.17
		1.00	.46	.68	6.33	7.90	14.23
period 3	.50	.00	.47	.47	7.30	8.14	15.45
		1.00	.49	.46	8.50	8.00	16.50
	.67	.00	.52	.61	8.45	7.68	16.13
		1.00	.53	.67	6.58	7.83	14.42
	.75	.00	.47	.61	7.50	8.50	16.00
		1.00	.39	.80	5.92	8.58	14.50
	Total	.00	.49	.58	7.84	8.10	15.94
		1.00	.46	.68	6.70	8.17	14.87

Table V.1: Average strategies (s_1, s_2), payoffs (u_1, u_2) and payoff sums $(u_1 + u_2)$ where "KNOWL" $= 1$ (0) means that w is initially known

As can be seen in Table V.1, Player 2 (the Parasite) – in accordance with both parts of Hypothesis 1 – is inclined to choose H with probability w. This inclination is stronger when the probability in Nature is known in advance and becomes even stronger with time. Whether, when the proportion with which Player 2 chooses H is lower than w, it reflects an inaccurate perception of w or a tendency on the part of some participants in the role of Player 2 to encourage Player 1 towards the Total Efficiency strategy (Hypothesis 3), will be discussed below.

Note that all three models predict a rather narrow range for Player 2 – between .5 and w – hence, assuming that Player 2 chooses, consciously or not, between the lines of action captured by these models, the decision problem of Player 2 as to what strategy to choose is not that big.

The situation is different for Player 1, for whom the different models define a much wider range of choices. The Unique Equilibrium model (UE) and the drive for equality dictate that H be chosen with probability $1 - w$ (Hypothesis 1 (i)); the Impulse Balance model (IB) calls for choosing H with probability .5 (Hypothesis 1 (ii)); and the search for Total Efficiency TE (Hypothesis 3) suggests that Player 1 always (or almost always) choose H. The dilemma, as to which strategy to adopt – expressed in the larger range of theoretically justified (or justifiable) options – is therefore much graver for Player 1.

Table V.1 shows that, on average, Player 1's strategy is closest to $s_1 = .5$. However, this average could be composed of different numbers of players employing the two more extreme strategies, namely, $1 - w$ and 1, or a combination of all three possibilities.

Table V.1 also makes clear which of the parts of Hypothesis 2 better describes participants' behavior. The sum $s_1 + s_2$ is clearly higher than 1, thus providing some signs of altruism (Hypothesis 2 (ii)).

To better understand the make up of the averages in Table V.1 (for the conditions in which $w > .5$) we divided the range between 0 and 1 into five categories:[9]

1. (min): s is close to 0;
2. $(1 - w)$: s is closer to $1 - w$ than to either 0 or .5;
3. (half): s is closer to .5 than to either $1 - w$ or w;
4. (w): s is closer to w than to either .5 or 1;
5. (max): s is close to 1.

[9] The ranges are somewhat different for $w = .67$ and for $w = .75$ as the distance between $1 - w$ and .5 and between .5 and w is smaller and the distance between 0 and $1 - w$ and that between w and 1 is bigger for $w = .67$. We nevertheless collapsed the results in both proportions of w.

Table V.2 presents the frequencies of these categories and category constellations for the Known and Unknown sessions separately for each of the three periods.

KNOWL		Period											
		1				2				3			
	s_1 \ s_2	$1-w$	0.5	w	max	$1-w$	0.5	w	max	$1-w$	0.5	w	max
0	min	—	—	—	—	—	—	—	—	—	—	—	1
	$1-w$	—	1	1	—	—	2	3	1	—	2	3	—
	0.5	1	12	5	—	2	6	3	—	1	4	4	2
	w	—	3	1	—	2	2	2	—	1	4	1	—
	max	—	—	—	—	—	—	1	—	—	1	—	—
1	min	—	—	—	—	—	—	—	1	—	—	3	1
	$1-w$	—	1	2	3	—	1	5	4	—	—	4	1
	0.5	—	2	6	1	—	2	4	1	—	—	8	—
	w	—	2	5	—	—	2	1	2	—	1	3	1
	max	1	—	1	—	—	—	—	1	—	—	1	1

Table V.2: Categorization of strategy vectors (s_1, s_2) for $w > 1/2$ separately for PERIOD (1, 2, 3) and KNOWL (0, 1)

As is clear from Table V.2, Player 2 gravitates, over time, towards w or even higher. Typically starting with half in the Unknown condition, a number of players shift into playing w or higher (max). In the Known condition w is the prototypical strategy of Player 2 already in Period 1, becoming even more common in Period 3.

Player 1 starts out playing half and this is true not only in the Unknown condition, where it is most pronounced, but also in the Known condition. Interestingly, the players then diverge: while some stay at half (in line with IB), some drift to choosing H with a lower probability (in line with the prediction of UE) and others towards choosing H with a higher probability (in line with TE). The distribution of Player 1's strategies is almost symmetrical above and below half, making it hard to decide which of the models better predicts their behavior.

To compare the goodness of prediction of the three models we calculated, for each player in each period, the distance between the proportion with which the player chose H and the proportion predicted by each of the three models.[10]

An analysis of variance on the differences between the each player's strategy and that predicted by each of the three models (with Model, Player and Period as a within pair measure and with Proportion in nature (w) and U/K (KNOWL) as between pair measures) revealed a significant effect of Model ($F(2, 88) = 11.37$, $p < .001$), with IB best predicting participants' behavior and the UE second. There is an interaction between Model und U/K ($F(2, 88) = 5.334$, $p = .007$) such that the advantage of IB over UE is more pronounced in the Unknown condition and over TE in the Known. Table V.3 presents the mean distance from each model for each player in each of the three periods.

			Mean	Std. Error	95% Confidence Interval	
Model	Player	Period			Lower Bound	Upper Bound
UE	1	1	.237	.018	.200	.274
		2	.205	.023	.158	.252
		3	.240	.022	.196	.285
	2	1	.133	.012	.109	.158
		2	.135	.015	.105	.165
		3	.110	.013	.084	.135
IB	1	1	.103	.011	.080	.126
		2	.154	.014	.126	.182
		3	.174	.019	.136	.212
	2	1	.133	.012	.109	.158
		2	.135	.015	.105	.165
		3	.110	.013	.084	.135
TE	1	1	.204	.016	.172	.235
		2	.258	.021	.215	.301
		3	.265	.026	.213	.318
	2	1	.141	.014	.114	.169
		2	.181	.016	.149	.213
		3	.190	.015	.161	.219

Table V.3: Mean deviations, standard errors and 95%-confidence intervals of theoretical benchmarks (MODEL = IB, UE, TE)

[10] Since Total Efficiency predicts for Player 1 a pure strategy – choosing H with probability 1 – and since a pure strategy is risky in this game, we modified the prediction into w for the model comparison, thereby helping this model to a certain extent. In spite of this modification, actual behavior deviated most from the predictions of the TE model.

A closer look reveals that IB predicts Player 1's behavior better than the other two. Still, it should be noted that, unlike the strategy of Player 2, for whom the prediction of both IB and UE improves over time (and that of TE decreases), the goodness of prediction of IB and TE for Player 1 decreases with time. The prediction of UE concerning Player 1 remains constant. The latter observation is expressed in a significant Model by Player by Period interaction: $F(4, 176) = 2.628$, $p = .036$). In sum, while IB best predicts participants' behavior, it does not account equally well for all participants, some of which are better described by the other contenders.

So far we have discussed the behavior of participants in each role, that of Player 1 and that of Player 2, separately. However, since the game was played with participants fully aware of each other (even though verbal communication was not allowed) it could be interesting to see what pair-wise constellations have evolved and which characteristics of the situation affected the emergence of these constellations.

Using the enumeration of the categories of strategies for each player (see above) - separately for each period - as the dependent measures, the correlations between the strategies of players in a pair were tested. The correlation is negative in all three periods (though not quite significantly so: $r = -.279$, $-.231$, and $-.262$, $p = .055$, $.114$, and $.073$ for periods 1, 2, and 3, respectively). These negative correlations indicate the emergence of distinct styles of interactions, as low values for s_1 and high for s_2 are characteristic of a competitive interaction (UE) whereas high values for s_1 and low values for s_2 are characteristic of a cooperative strategy (TE): a more risky behavior on the part of Player 1 leads to higher overall efficiency with Player 2 not taking advantage of Player 1's strategy.

Is any of the two players more responsible for the eventual style of interaction? A correlation between the strategy of a player in a later period with that of the other player in an earlier period may suggest who leads and who follows suit. Such a correlation is to be found between the strategy of Player 1 in Period 2 and the strategy of Player 2 in Period 1 ($r = -.339$, $p = .018$). Apparently, lack of generosity on the part of Player 2 in Period 1 drives Player 1 to be competitive, lowering the probability with which H is chosen.

How is the size of participants' WM, as measured in the digit-span task, related to their choice of strategy? To find out, we have looked at five different measures: The capacity of Player 1, the capacity of Player 2, the difference between the capacity of Player 1 and Player 2, the absolute difference in capacity, and the sum of the two capacities.

Of the five measures, the absolute difference in capacity between the two players was the only one significantly correlating with strategic aspects of the play: When the absolute difference in WM capacity was greater, there was an increased tendency to start competing early. Hence, in Period 1 the absolute difference in WM was negatively correlated to s_1 ($r = -.302$, $p = .037$) and positively correlated to s_2 ($r = .338$, $p = .019$). In the following periods the negative correlation with s_1 weakens and the positive correlation with s_2 disappears. Apparently, some pairs that did not differ in WM also adopted a competitive stance later in the game.

One may wonder what it was in participants' behavior that made their partners notice the difference in WM capacity and modify their strategy accordingly. Given that the capacity of each player alone did not correlate with strategy they may have sensed it by other characteristics of their play. Future research, testing further the effects of working memory capacity on competitive behavior may provide an answer to this question and prove a rich source of insights into people's behavior.

6 Conclusions

There is a sad lesson to learn from the Parasite Game. Looking again at Table IV.2, it is clear that, as the regularity in nature increases – from $w = .5$ through $w = .67$ to $w = .75$ – the potential reward for the pair increases from 50 through 67 to 75 NIS. Moreover, it is clearly easier to take advantage of this regularity when known in advance than when it has to be discovered through experience and it is easier to discover the regularity through experience the more it deviates from .5 (i.e., when $w = .75$). However, as Table V.1 indicates, participants did not make good use of the regularity in nature. Instead of a pair earning much more from a more regular nature they earn less, and even less when they know of the regularity than when they do not.

Another way to look at the effects of regularity and advance knowledge is to note that the situation in which participants could gain most – the Known condition of $w = .75$ – is the situation in which they are farthest away from the predictions of the Total Efficiency model and as a result gained least. Lack of generosity on the part of Player 2, driving Player 1 to decrease efficiency, resulted in lesser gains for both.

To summarize, we have found a number of factors driving participants into harmful opportunism while they attempt to exploit nature in the face of competition. These are the sense of difference (as expressed by the effect of the difference in WM capacity), advance knowledge of the potential gains and the size of the potential gains. Apparently, the abundance of milk and honey and the knowledge thereof drive the disparate partners to continuous competition.

Concerning the benchmark solutions none of them is convincingly supported by the average tendencies. The more detailed analysis revealed, however, that they can at least account for certain clusters of play. So, for instance, plays with s_1 close to $1/2$ and s_2 close to w are rather frequently observed and can be justified by the impulse balance equilibrium. Since only one parameter, the probability w of nature's choice, has been varied systematically in addition to the way how w is learned, we refrain from a general evaluation. This should be based on a meta-analysis of a larger variety of experimental games.

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Appendix A: Experimental protocol

The experiment involved two players and an experimenter.

First, each player was given a standard digit-span test in which the maximal length of a list of digits a participant can remember perfectly is measured. Participants were rewarded $\frac{1}{2}$NIS for each digit in the longest list they could remember.

Then the instructions for the game were read aloud (see Appendix B) and a coin was tossed to determine who will be Player 1 and who Player 2.

The game proceeded for 99 or 100 rounds. When the game ended the tokens were traded for cash - 1 NIS for each token.

Appendix B: Instructions for the Parasite Game*

We shall play a game of two participants, Player A and Player B, who will be determined by the toss of a coin that we shall conduct now.

I will explain the procedure of the game and ask you not to talk to one another from now on. Any talk or communication between you will cause an interruption of the game.

The procedure of the game:

Here are twelve tokens, some red and some green. Four of the tokens are green and 8 are red. I will now put all these tokens to the box in front of you**. On every round, each of you will choose red or green color by moving the marked square in the apparatus that you have to reveal the color that you chose. You have to do that while hiding the apparatus under the table and show it only when I say so. At the same time, I will draw one token out of the box and show it to you.

If the color chosen by Player A will be the color of the token taken out and the color that Player B chose is different - Player A will get a token worth 1 NIS.

If the color that Player A chose is the color of the token taken out and the color that Player B chose is also the same - Player B will get a token worth 1 NIS.

If the color that Player A chose is different from the color of the token taken out of the box - none of the players gains anything.

We shall perform this a hundred times, and it is, of course, worth your while to earn as many tokens as you can. In the end of the game we shall count the tokens and each of you will get paid. Are the instructions clear or do you want me to repeat them?

* The game was advertised as "The Color Game" to prevent any preliminary expectations on the parts of participants concerning parasitic behavior.

** This is the version for $w = 2/3$, proportion **known**. Obvious modifications were made for in different treatments.