Which Way to Cooperate*

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October 2011
Forthcoming in *the Economic Journal*

Abstract

We introduce a two-player, binary-choice game in which both players have a privately known incentive to enter, yet the combined surplus is highest if only one enters. Repetition of this game admits two distinct ways to cooperate: turn taking and cutoffs, which rely on the player's private value to entry. A series of experiments highlights the role of private information in determining which mode players adopt. If an individual's entry values vary little (e.g., mundane tasks), taking turns is likely; if these potential values are diverse (e.g., difficult tasks that differentiate individuals by skill or preferences), cutoff cooperation emerges. *JEL* classification nos.: C90, Z13.

*We thank Douglas Bernheim, Valin Dittrich, Dirk Engelmann, Jim Engle-Warnick, Naomi Feldman, Guillaume Fréchette, Andrew Muller, Jim Myton, Ariel Rubinstein, Tim Salmon, Mike Stutzer, numerous seminar and conference participants and especially two anonymous referees and the editor, David Myatt, for valuable comments. Tzvi Kerpzseld, Kadia Kohelet, Shy Maman, Tim Miller, Eran Ozery, Gad Rotman, Asaf Shaul, Tal Shavit, Ron Stern and Yael Uzen offered valuable research assistance. Kaplan thanks the Economic and Social Research Council (grant no. RES-000-22-0370) and Ruffle thanks the Israel Science Foundation (grant no. 776/03) for generous financial support.

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1 Introduction

We investigate two modes of cooperation (namely, alternating and cutoff cooperation) that feature prominently in real-world cooperation dilemmas and, through a series of experiments, characterise when each one is likely to arise. We then apply the insights from our experimental findings to understand why some dilemmas are resolved through alternating while others via cutoff cooperation.

Firms that face one another in multiple markets can collude by alternately competing and acquiescing in markets or by staying out of their less profitable markets. Auction participants who compete for similar objects auctioned off sequentially can collude by taking turns bidding on objects or by bidding only on sufficiently valuable objects. Cab drivers at a taxi stand are assigned to passengers according to an agreed upon order, whereas roaming cabbies divvy up the dispatchers calls on a case-by-base basis, mostly by proximity to the passenger's location.

While the above examples illustrate multiple modes of cooperation, to the best of our knowledge, there are no previous papers that systematically address the form cooperation takes. A large economics literature exists on cooperation in experimental games. However, roughly speaking, this literature asks whether cooperation arises under one set of circumstances or another. The reason for this oversight is straightforward: standard cooperation games are inadequate since they allow for only one mode of cooperation.

We introduce a class of two-player games in which to defect is the dominant strategy, but the social optimum requires one player to cooperate (and earn nothing) and the other to defect (and earn the entire available surplus). To reach the socially efficient outcome entails the pair coordinating on which player will cooperate and who gets to defect. Consider the following game: each player privately receives a randomly drawn value, an integer between 1 and 5 inclusive, each with equal probability. Each player then decides between one of two actions: enter or exit. By exiting a player receives zero. By entering, he receives his number if his partner exits and one-third of his number if his partner also enters.[1] Notice that entry is the dominant strategy in

[1] For the purposes of brevity and consistency, we will refer to the person with whom the player is paired as the player's "partner". In the experimental instructions, the more neutral phrase "the person with whom you are

this game. At the same time, entry involves congestion in the sense that it reduces the partner's payoff if he enters too. Finally, this congestion is of sufficient magnitude such that the first-best cooperative outcome requires the high-value player to enter and the other, low-value player to stay out. This outcome can be achieved only when players know each others' values before making a decision.

If values are instead private and cannot be communicated or signaled, the first-best outcome is no longer feasible. Cutoff cooperation and alternation are two repeated-game cooperative norms that avoid the inefficient stage-game dominant strategy of always entering. Cutoff cooperation entails entering when the value to doing so exceeds some threshold (e.g., 2.5 in our game) and not entering otherwise. Cutoff strategies thus condition on players' private information. Unlike cutoff cooperation, alternating ignores private values; rather, it makes use of publicly available information, like the time of day, the auction number in the sequence or round number (e.g., enter in even-numbered rounds only, while the other player enters only in odd rounds).

This game structure and its inherent properties are mirrored in many real-world dilemmas in which the overall surplus is increased when one participant chooses not to enter, even though entry is in his self-interest. Two companies bidding for a government contract can collude by having only one company submit a bid; whereas, both actively bidding reduces each bidder's expected probability of winning to one half and inflates the price paid by the eventual winner, thereby reducing each active bidder's expected surplus by more than half, analogous to the congestion following from both entering in our design. Kwasnica (2000) presents experimental evidence from repeated auctions in which bidders collude by taking turns bidding across different auctions, referred to as bid rotation. Baseball-card manufacturers (Zillante, 2005) and the motion-picture industry (Einav, 2010) stagger new-product-release dates to blunt competition. Lau and Mui (forthcoming) note the use of alternating to resolve a range of common-pool-resource dilemmas.[2] Helbing et al. (2005) study turn taking to avoid traffic congestion in route-choice games.

paired" was used.

[2]Their paper contains additional references to the use of alternating and they derive alternating as an equilibrium (along with some testable comparative-statics implications) for a wide-class of symmetric 2x2 games that includes many of the games discussed in section 3. In a series of such indefinitely repeated laboratory games,

Harcourt et al. (2010) show that pairs of fish that forage together to avoid predation alternate between each's preferred site. This literature focuses on alternating without comparing it to other cooperative strategies, such as cutoffs.

Cutoff cooperation is much more difficult to detect outside the laboratory because players' values for pursuing the action are usually unobservable to the researcher and repeated decisions to enter or exit according to cutoff strategies exhibit no discernible pattern. Still, several examples of cooperation appear to correspond to cutoff strategies. For instance, political parties hold primaries to agree on which candidate will represent the party in the upcoming election. Which candidate boasts a better chance of defeating the other party is a central consideration in choosing the winner of the primary. In the language of our model, similar to cutoff strategies, the candidate with the higher expected value enters, while his competitor agrees to stay out. Political primaries serve the purpose of avoiding the outcome whereby both candidates run for election, split their supporters' vote and allow the other party's lone contestant to win.[3]

In other settings resembling our game structure, both alternating and cutoff cooperation may be employed, depending on the circumstances. Two firms competing sequentially in multiple geographic or product markets may individually find it profitable to enter each and every market. However, by doing so, firms obtain half the market in expectation, lower prices and expend resources on advertising in an effort to lure customers away from their competitor, thereby reducing each other's profitability by more than half. More efficiently, firms may collude by

Cason et al. (2010) link subjects' ability to implement efficient alternating to experience with alternating in a previous game.

[3]Relatedly, former U.S. President Bill Clinton had these interests in mind when he asked the lone Democratic candidate, Kendrick Meek, to drop out of the 2010 Senate elections to avoid the outcome where Democratic supporters split their vote between Meek and the moderate Independent candidate, Charlie Crist, allowing the Republican, Marco Rubio, to win. Meek refused and Clinton's concern came to pass (see Wolf, 2010). Similarly, in the 1970 New York Senate election, the two liberal candidates garnered a combined 61% of the vote, losing to the sole conservative candidate, James R. Buckley (see Myatt, 2007). Finally, after losing the Republican primary, Teddy Roosevelt formed the Bull Moose Party to run for president which resulted in Republican supporters splitting their vote between Roosevelt and the incumbent Republican nominee Taft in the 1912 elections, allowing the Democrat Woodrow Wilson to win.

alternately entering and staying out of markets such that exactly one firm enters each market or by deciding independently which markets to enter based on their profitability (which may differ across firms and across markets according to, for example, geographic proximity to the market, a firm's degree of specialization in the product market in question or other cost-related differences).

Moreover, most taxi drivers in Europe work with a cab company and thus play a repeated game with the company's other cab drivers. While all cab drivers may want to serve every fare who comes their way, cabbies arguing over passengers waste time and may prompt passengers to take their business elsewhere. To avoid conflict, at the company's taxi stand cabbies take turns serving passengers according to an observable, namely, who has been waiting the longest; whereas, when a passenger calls the cab company, only cabbies with high values for taking the passenger volunteer, like cutoff cooperation; cabbies who already have a fare or who aren't in the vicinity of the passenger acquiesce. More generally, workers in markets characterised by excess labor supply regularly face the decision whether to compete for a customer or withdraw: restaurant waitstaff, bicycle messengers, golf caddies, sky caps and two car salespersons at the same dealership. Workers in these industries have every incentive to reach a cooperative solution to avoid fighting over customers, sending a signal of unprofessionalism and the customer fleeing.

In procurement auctions, we've already noted the potential for alternation according to object number or "phases of the moon" (Hendricks and Porter, 1989). Cutoff cooperation also seems plausible: a firm bids only if its value for the contract is sufficiently high. However, collusion in auctions is difficult to confirm in any form due to its illegality and to the fact that bid rotation in procurement auctions is a Nash-equilibrium outcome under decreasing returns to scale (Zona, 1986; Porter and Zona, 1993). Hence real-world data cannot typically distinguish between bid rotation as a competitive or a collusive outcome. Our experiments can.

Finally, two female friends cruising the town confront repeatedly the dilemma of deciding who gets to pursue the men they encounter. To resolve quickly who pursues which men and avoid fighting over potential companions, these friends could agree to divide up the desirable men by taking turns or, equivalently, by observable characteristics like height or hair colour or, similar to cutoff strategies, by each relinquishing males they find less attractive.

Notice that in all of these examples, we've stressed that each player's expected payoff when both pursue the action is strictly less than half the payoff compared to one sole pursuant. This corresponds to our game's payoff structure according to which if both players enter, each receives only one-third of his respective value. The examples differ according to whether this negative externality of entry results from conflict, increased effort required or a reduced chance of earning the surplus when the other competitor also pursues the action. Furthermore, in all but the auction and multi-market contact examples, which way players cooperate is determined through communication and its implementation sometimes even requires a third party (e.g., the cab dispatcher or maitre d' in the examples characterised by excess labor supply). In our experiments, paired players unable to communicate with one another face the challenge of arriving endogenously at one cooperative norm or the other. Whether they are able to cooperate at all and which cooperative norm they reach are the focus of this paper.

When are some cooperative dilemmas resolved by alternating, while others are dealt with by cutoff cooperation? To answer this question, we designed the above game, its parameters chosen because the socially optimal cutoff and the alternating strategies yield similar joint expected payoffs. We conduct this game for 80 rounds under two private-information treatments that differ according to the point in time at which a player learns his opponent's number (at the end of the round or not at all). We find that the socially optimal symmetric cutoff strategy whereby a player enters on the numbers 3, 4 and 5, and exits otherwise is subjects' modal choice in both treatments. Surprisingly few subjects in either treatment adopt alternation, despite its ease of detection, strategic simplicity and ubiquity in real-world cooperation dilemmas.

In an effort to understand why so few subjects alternate, we designed an additional pair of treatments in which we added a constant of 100 to all of the entry values. This change renders the entry values similar to one another, thereby reducing the importance of players' private information, while leaving unchanged the inherent difficulty of both players coordinating on alternation. The results from these follow-up treatments reveal that at least 95% of all cooperators in both treatments employ alternation. Thus, a single change to the game parameters, namely, the addition of a constant to all entry values, produces a dramatic switch in the observed cooperative norm from cutoff cooperation to alternation. This finding provides insights into the form cooperation can be expected to take.

In the next section, we develop the theoretical framework for this class of games and show how we arrive at the above parametrisation. We contrast our game with familiar cooperation and coordination games in section 3. In section 4, we detail our experimental design and procedures. Section 5 presents theoretical results on cooperation for the infinitely repeated game, which yield testable experimental hypotheses. Section 6 presents the experimental results and provides possible explanations for the paucity of alternating in these experiments. Section 7 reports the results of additional treatments designed to differentiate between these explanations. Section 8 concludes with insights into when to expect alternation versus cutoff strategies in cooperation dilemmas outside the laboratory.

2 Theoretical Framework

In this section, we introduce a class of two-player games. We begin by solving for the equilibrium and socially optimal outcomes of the one-shot game (also relevant to the finitely repeated game).[4] We derive additional theoretical and comparative-statics results, which will help guide our choice of game parametrisation for the subsequent experiments and may also be of some independent interest since these games haven't previously been studied. All proofs appear in Appendix A.

2.1 *Environment*

We propose a two-player game with the following general structure. Each player receives a private number drawn independently from a discrete distribution on $\{\underline{v}, \ldots, \overline{v}\}$ where the probability of receiving a number x is π_x (where $\pi_x > 0$ and $\sum_{x \in \{\underline{v}, \ldots, \overline{v}\}} \pi_x = 1$). Without communication between themselves or a mutual third party, players simultaneously make a binary decision $A = \{enter, exit\}$. By exiting a player receives zero. By entering he receives his number if the

[4] See Section 5 for the repeated-game analysis.

other player exits. If both enter, he receives a function, $f(x, y)$, increasing in his number, x, and possibly also a function of the other player's number, y.[5] We assume that $f(x, y)$ is strictly less than the player's number x; hence entry imposes a negative externality on the other player. We also assume that if it is profitable for a player to enter alone ($x > 0$), then it is also profitable for him to enter when his opponent enters ($f > 0$ for $x > 0$).

2.2 *Solutions*

There are noncooperative and cooperative solutions to this one-shot game. For the noncooperative solution, if each player is concerned about maximizing only his own payoff, then we solve for the Bayes-Nash equilibrium. This yields the dominant strategy of entry for numbers greater than zero.

Suppose that one player enters with probability $p_1(x)$ when his number is x and the other player enters with probability $p_2(y)$ when his number is y. These form a cooperative solution if they maximise the joint expected payoff:

$$\sum_{x \in \{\underline{v} \dots \overline{v}\}} \sum_{y \in \{\underline{v} \dots \overline{v}\}} \pi_x \pi_y \Big[x p_1(x)\big(1 - p_2(y)\big) + y\big(1 - p_1(x)\big)p_2(y) + p_1(x)p_2(y)\big(f(x, y) + f(y, x)\big)\Big].$$

PROPOSITION 1. *If $f(x, y)$ is strictly increasing in one argument and weakly increasing in the other, then the cooperative solution entails cutoff strategies for both players (that is, for $\underline{v} \leq z < \overline{v}$ and $i = 1, 2$ if $p_i(z) > 0$, then for all $z' > z$, $p_i(z') = 1$).*

Appendix A contains the proof of this proposition as well as a general solution for the value of the socially optimal pure-strategy cutoff. Monotonicity explains why if it is profitable to enter on x, then it is also profitable to enter on any number greater than x. As we will show, these cutoff values may be non-interior and even asymmetric. For instance, if $f(x, y) + f(y, x) > \max\{x, y\}$, then the social optimum is non-interior – both always enter.

[5] Consider a second-price auction. If a player doesn't submit the highest bid, $f(x, y) = 0$. Otherwise, $f(x, y) = x - g(y)$ where $g(y) = y$ if players bid competitively and $g(y) < y$ if players employ a cooperative bid-reduction strategy.

A pure-strategy cutoff is when there exists a c^* such that for all $x \leq c^*$, $p(x) = 0$ and for all $x > c^*$, $p(x) = 1$. An extreme form of asymmetric pure-strategy cutoffs involves one player using $c_i^* < \underline{v}$ (i.e., always enter) and the other $c_j^* > \overline{v}$ (i.e., always exit). In a repeated game, this cooperative solution can admit the form of players taking turns entering. A mixed-strategy cutoff is when there exists an x such that $0 < p(x) < 1$. The proposition implies that it is never optimal to mix on more than one number in the range.

To simplify the game for experimental subjects, we restrict $f(x, y)$ to be of the form x/k (where $k \geq 1$ is the congestion parameter). This restriction enables us to solve for the socially optimal pure-strategy symmetric cutoff as a function of the game parameters for a uniform distribution of values (see Proposition A1 in Appendix A). Corollary A2 in Appendix A shows that such a cutoff always involves some measure of cooperation by exiting on at least the lowest integer, $\underline{v}$. The restriction on f also allows us to determine the socially optimal mode of cooperation for particular cases.

PROPOSITION 2. *(i) For any distribution of values, when $k \leq 2$, the socially optimal strategy is a cutoff strategy; (ii) When the distribution of values is uniform, as $k \to \infty$, the socially optimal strategy is alternating.*

When the distribution of values is not uniform, Proposition 2 (ii) does not generally hold. Take for example the values of 100 with probability 1/3 and 1 with probability 2/3. For large k, alternating yields a joint expected payoff of 34. Entering only when one has 100 yields 100 with probability 4/9 and ϵ otherwise. Hence, this optimal cutoff strategy yields a higher joint expected payoff.

2.3 *Choosing a Particular Game*

With the goal of determining which form of cooperation subjects employ, we had two objectives in choosing a game parametrisation: 1) to design a game for which the joint expected payoffs from alternation and the socially optimal pure-strategy symmetric cutoff strategy are similar; 2) to maximise the difference between the joint expected payoffs from playing the optimal symmetric pure-strategy cutoff, c^*, and the second-best symmetric pure-strategy cutoff, that is, to maximise the steepness of the joint expected payoff function around c^*. Achieving this second goal gives us greater confidence in interpreting deviations from c^* as an intention not to cooperate optimally.

In our search for a parametrisation, Proposition 2 suggests values of k greater than 2, but not too large in order to achieve objective 1. We allowed k to vary from 2 to 5. Using the uniform distribution over the range of integers, $\{\underline{v}, \ldots, \overline{v}\}$, we allowed $\overline{v}$ to be any integer greater than or equal to 3, and fixed $\underline{v} = 1$ to ensure enter is a dominant strategy.

Our search led to $(\overline{v} = 5, k = 3)$. Table 1 indicates the pair's joint expected payoff for all pure-strategy cutoffs and alternating for our chosen parametrisation.[6] Alternation earns the pair 3 units of profit in expectation, a mere 0.12 units more than the optimal symmetric cutoff, $c^* = 2.5$. That these two strategies perform almost equally well despite their qualitatively different natures raises the empirical question of which one, if any, will be adopted by players. Not only is the pair's expected payoff from alternating (3) higher compared to the optimal cutoff strategy (2.88), the variance of the expected payoff is also lower: 2 compared to 2.42.

For numerical examples that correspond to our chosen parametrisation, consider any two-player contest or competition with only one winner. If only one player enters, he is declared the winner and earns x. Entry is free, but imposes a negative externality in the form of increasing the other player's costs and lowering his probability of winning: if both enter, each spends $x/6$ (e.g., fighting, lobbying, advertising, opportunity cost) in an effort to win. The winner is chosen randomly among the entrants. Thus, in the event that both enter, each earns an expected surplus of $x/2 - x/6 = x/3$, implying $k = 3$.

There are also examples in which the negative externality comes solely in the form of lowering the other player's probability of winning (without increasing his costs). Consider, for instance, an auction with an entry cost of x. The value to winning the auction is $4x$. Thus, a lone entrant is ensured of winning and earns a net surplus of $3x$. However, if both enter, they collude and each

[6] An optimal solution in mixed strategies should be avoided due to the salience of the almost optimal, pure strategies in the support, the improbability that both subjects will solve for, and play, the optimal mixed-strategy cutoff and the added difficulty in determining whether subjects are playing mixed strategies.

is assigned the object with probability 0.5, leading to a net expected surplus of $4x/2 - x = x$, implying $k = 3$.[7]

Similarly, consider repeated Bertrand competition between two firms selling homogeneous goods. Each firm has random costs equal to $5 - x$. Suppose there are four consumers, each willing to pay 5 for a single unit of the good. To introduce a product to market, a firm must give away one unit (a sample) at cost. If one firm enters, it charges 5 and sells to the three remaining consumers. If both firms enter, they maintain the collusive price at 5, each selling to one of the two remaining customers, implying $k = 3$. Relatedly, Athey and Bagwell (2001) study theoretically a repeated two-firm Bertrand game with private *iid* production costs each period. Unlike our game, firms are able to make a non-credible announcement and there is no congestion (no entry cost) in their setup ($k = 2$). With discrete costs, they find a collusive scheme in which only the low-cost firm (or firms) produces.

Textbook Cournot competition also illustrates the negative externality of entry present in our game. With constant marginal cost c and linear inverse demand $P = 1 - Q$, a Cournot monopolist's profit equals $(1 - c)^2/4$, whereas a duopolist earns $(1 - c)^2/9$, implying $k = 9/4$. Adding fixed entry costs leads to higher values of k.

Advance-fee fraud, most often distributed by e-mail spam, also shares our game's structure and a strong negative externality of entry in the form of severely reducing other scammers' chances of success. At first glance, individual scammers might aim to distribute their low-probability-of-success messages as widely as possible. However, a recipient who receives *two* notifications of a significant inheritance from a long-lost relative or of having won the lottery at

[7] Alternatively, consider an auction with two bidders in which two objects with complementarities are sold. A player who wins one of the objects earns v, while obtaining both objects yields $6v$. Suppose that players who choose to enter employ a minimum-bid scheme: namely, enter and bid the minimum bid of 0. If only one player enters, he earns $6v$. If, however, both enter (with a bid of 0), each of the objects is randomly and independently assigned to one of the entrants. Thus, there is a 1/4 chance that one player wins both objects, a 1/2 chance that he wins only one object and a 1/4 chance of leaving empty-handed. Hence, a player's expected profit is $6v/4 + v/2 = 2v$, implying $k = 3$. Kwasnica and Sherstyuk (2007) study experimentally complementarities in repeated auctions. They find that in markets characterised by collusion, the most common form is bid rotation (allowing one subject to win both complementary objects).

once recognises them as spam. If scammers could coordinate, they would divide up the lists of e-mail addresses such that no recipient receives more than one fraudulent offer. Some forms of advertising, sales techniques, marketing gimmicks and pick-up lines share this property whereby the tactic may work once on the unsuspecting target. But two exposures to the identical tactic are often sufficient to alert the target to the ploy, thereby drastically diminishing the likelihood of a sale ($k >> 2$).

Finally, the negative externality of entry can increase the other player's costs without reducing his chances of winning. Consider two equally gifted job candidates from the same class of the same university department working on similar topics. Both are on the academic job market. Their talents and plenty of relevant job openings ensure that both will get jobs they find satisfactory. The remaining question is how much effort it will take them. If both apply to the same set of job openings, they may both be eliminated early on because each detracts from the other's uniqueness; or they may face a lengthy recruiting process because the interested department has difficulty deciding which of the two it prefers. The pair of candidates is better off dividing up the (alphabetically ordered) list of potential employers by alternating or by playing cutoff strategies (perhaps with a budget of values each is able to assign in total).

3 Related Games

It is tempting to equate our game with an existing, standard 2x2 game in the literature. Yet, to do so is to ignore some of the properties of our game, which combines the coordination required in a market entry, chicken or battle-of-the-sexes game with the cooperation required in a prisoners' dilemma game. To avoid this confusion, we compare the structure of our game to several well known games in this section.

The best known cooperation game, the prisoners' dilemma (PD), has a unique dominant-strategy equilibrium in the one-shot game in which both players defect; however, if both players could commit to cooperation, both would be better off. Likewise, in the standard public-goods game (PG) (an n-player extension of the PD), the socially optimal outcome involves all players contributing their endowments to a public good, which conflicts with the unique dominant-strategy equilibrium in which each player contributes to a private good. Noncooperation (enter) is also the unique dominant-strategy equilibrium of our class of games. Unlike the standard PD and PG games, the socially optimal outcome in our game involves one person playing his dominant strategy and the other playing his dominated strategy. A second distinction of our game is that if both players choose their dominant strategies they are better off than if both play their dominated strategies.

Van de Kragt, Dawes and Orbell (1983) introduce a variation of the standard public goods game in which a minimum aggregate contribution to the public good is required for its provision. In these threshold or step-level public goods games, there is no dominant strategy since each player prefers to contribute if and only if his contribution is pivotal in ensuring the good's provision.

Amnon Rapoport and his coauthors have conducted various versions of a market-entry game first introduced by Farrell (1987) and Kahneman (1988). In an early version most closely related to ours, Rapoport (1995), n symmetric players independently decide whether to enter a market with capacity $c \leq n$. Staying out yields a fixed payoff, whereas entering yields a payoff that decreases in the number of entrants and yields less than the fixed payoff from staying out in the case of excess entry.[8] These games have large numbers of pure-strategy and mixed-strategy equilibria, all efficient and all characterised by some subset of players entering with positive probability. By contrast, our game has a unique Nash equilibrium, which is inefficient and at odds with the full-information, social optimum whereby one player enters and the other exits. Moreover, exit is a strictly dominated strategy in our game. Put another way, if both players enter ("excess entry"), unlike the market entry game, each entrant still earns more than if he had exited.

For a particular realization of players' numbers, Table 2 makes precise the differences between our game and others. The top row and left column are the cooperate/exit/swerve action (de-

[8]The special case in which the payoff for entering changes only in going from within-capacity to over-capacity is known as the El Farol Problem (see Arthur, 1994).

pending on the game in question). The bottom row and right column are the defect/enter/not swerve action. Normalizing the off-diagonal payoffs to (1,0) and (0,1), we denote the payoffs from the cooperative outcome as (a, a) and from the defect outcome as (b, b).

The standard PD and PG games restrict $a > b > 0$ and $a < 1$, but $2a > 1$ in order for the cooperative outcome to be efficient.[9] Threshold public goods games require $1/2 > a > 0 > b$.[10] For the market-entry game, $a = 0$ and $b < 0$. The game of chicken can be characterised by $1 > a > 0 > b$. It has the same asymmetric equilibria as the market-entry game and can be seen as a limiting case of it as a decreases to 0. For both games, the pure-strategy Nash equilibria are also the socially optimal outcomes. For the battle-of-the-sexes game the pure-strategy Nash equilibria also correspond to the social optima, although they are the diagonal outcomes. Finally, our game requires $b > a = 0$, and $2b < 1$ to ensure that the off-diagonal outcomes are efficient. For efficiency, our game requires both deviating from the equilibrium and coordinating on the off-diagonals. Private information further complicates this task by making it difficult to coordinate on any social optimum at all.

4 Experimental Design and Procedures

All experiments were conducted using z-Tree software (Fischbacher, 2007) in fixed pairs for 80 rounds. Each player in the pair received an independently and randomly drawn integer between 1 and 5 in each round. Subsequently, each player decided independently whether to enter or exit. The decision to exit yields 0, whereas entry yields the value of the number if the partner exits and 1/3 of the value of the number if the partner also enters.

At the end of each round, a player observes his partner's decision to enter or exit. We conducted two experimental treatments that differ by the point in time at which a player learns

[9] Dixit and Skeath (1999) do not place the $2a > 1$ restriction on the PD, thereby allowing for a social optimum in which one player defects while the other cooperates as in our game.

[10] Hirshleifer (1983) and Harrison and Hirshleifer (1989) introduce a best-shot public goods game in which the amount of public good provided is determined solely by the maximum individual contribution, implying $2a < 1$. However, their game also restricts $a = 0 > b$ (see Table 4 of Harrison and Hirshleifer). Thus, the off-diagonals are both socially optimal and the pure-strategy Nash equilibria of their game.

his partner's value (after the round or never). In "*After*", at the end of each round, each player learns his partner's decision and value. In "*Never*", a player does not observe his partner's number at the end of the round, only his decision to enter or exit.

The *After* treatment provides relatively favorable conditions for cooperation since the pair may coordinate on and enforce both alternation and cutoff strategies. If a player enters when it is not his turn or on a low number, say 1, he recognises that his partner will observe this defection and can retaliate by entering out of turn or the next time he receives a 1.

In *Never*, deviations from alternating strategies are easily detected and punishable; whereas, defection from cooperative cutoff strategies is more difficult to detect. This lack of information in *Never* renders cooperative cutoff strategies unlikely. A player does not know if his partner entered because he is playing uncooperatively or because he drew a high number. Frequent entry may just reflect lucky draws of high numbers. A rule could be adopted whereby more than seven entries in the past 10 rounds constitutes a deviation; yet, efficiency would be lost if more than seven of the last 10 draws exceeded the cutoff of 2.5. Furthermore, coordination upon the rule of seven out of 10 or any other could prove difficult. Indeed, Engelmann and Grimm (2008) explore a repeated voting game that requires truthfulness in voting in order to achieve efficiency. Just as in our game, a partner's truth-telling can be deduced statistically only over a number of rounds. They find that an exogenously imposed rule, the equivalent to being allowed to enter at most 40 out of 80 rounds in our game, helps efficiency.[11] However, in the absence of a rule, low levels of cooperation result. In an additional treatment, they find that deciding four rounds at once partially helps cooperation by providing a focal point on which to coordinate (enter in exactly two of the four). In our setup, no such focal point exists.

Upon arrival, each subject was seated in front of a computer terminal and handed the sheet of instructions (see Appendix B). After all subjects in the session had read the instructions, the experimenter read them aloud. To ensure full comprehension of the game, subjects were given a series of knowledge-testing questions about the game (available from the authors upon request).

[11] Note that Engelmann and Grimm (2008) ran their experiments for 40 rounds and implemented an entry budget of 20 out of 40 rounds.

Participation in the experiment was contingent upon answering correctly all of the questions.[12] Five practice rounds were then conducted with identical rules to the actual experiment. To minimise the influence of the practice rounds, subjects were rematched with a different partner for the 80-round experiment.

An important feature of our experimental design that allows us to compare subjects' behaviour across pairs and across treatments is our use of one pair of randomly drawn sequences of 85 numbers (including the five practice rounds) from 1 to 5. Before beginning the experiments, we drew two 85-round sequences, one for each pair member. We applied these sequences to all subject pairs in all sessions and treatments.

We recruited subjects from a broad range of faculties and departments at Ben-Gurion University. Sixty-two subjects participated in one of the three *After* sessions and a different 62 subjects participated in one of the three *Never* sessions. In both treatments, one unit of experimental currency was exchanged for 0.6 shekels at the end of the session. A session lasted about 100 minutes on average, including the instructions phase and post-experiment questionnaire. Including a ten-shekel showup fee, the average subject profit was 76 shekels (about $20 USD at the time).

5 Cooperation in the Repeated Game

In the finitely repeated version of our incomplete-information game, neither alternating nor cooperative cutoffs can be supported as sequential-equilibrium strategies regardless of treatment. The dominant stage-game strategy of always enter remains the unique equilibrium. The socially optimal cutoff strategy remains the same as in the stage game ($c^* = 2.5$), while alternation is equivalent to asymmetric cutoffs whereby one player enters and the other exits in the stage game.

Whether cooperative cutoffs and alternation can be supported as equilibria in the infinitely repeated game is of interest because 80 repetitions raise the possibility that partners behave as if the game is infinitely repeated. Indeed, with a sufficiently long horizon, subjects sustain coop-

[12]No one was excluded from participating. All subjects who showed up answered correctly all of the questions in the allotted time.

eration in finitely repeated prisoner's dilemmas and public goods games until the final rounds.[13] Kreps et al. (1982) demonstrate theoretically that uncertainty about whether one's partner maximises his monetary payoff can support cooperation as an equilibrium outcome in the finitely repeated prisoner's dilemma.

The following proposition shows that in the infinitely repeated game, for a sufficiently high discount factor, players will not deviate from alternation in *After* or *Never* nor from symmetric cooperative cutoff strategies in *After*, or in *Never* if cutoffs are history-dependent.

PROPOSITION 3. *In an infinitely repeated game, for sufficiently patient players (high δ):*
(i) Alternation is a sequential-equilibrium (SE) strategy for the paired players in both the After and Never treatments;
(ii) The symmetric cooperative cutoffs $c = 1.5$, $c^* = 2.5$ and $c = 3.5$ are additional SE strategies in the infinitely repeated game in the After treatment only;
(iii) It is possible to support cutoff cooperation as a SE in Never, but only when strategies consist of history-dependent actions.

According to Proposition 3 (i), both *After* and *Never* can support alternation, while only *After* can support cooperative cutoff strategies according to 3 (ii). Taken together, we would expect more alternation in *Never* since (non-history-dependent) cooperative cutoffs are not available as a substitute.

From Proposition 3 (iii), if cutoff cooperation is played in *Never*, then the equilibrium cutoff value responds dynamically to the player's history of values and entry decisions. Thus, any attempt to categorise their play in *Never* as pure-strategy cutoffs will lead to higher error rates compared to *After* in which, by 3 (ii), pure-strategy cutoffs can be supported in equilibrium. In brief, multiple, qualitatively distinct equilibria exist. The experiments will inform us which ones are likely to be played in practice.

[13]See, e.g., Selten and Stoecker (1986), Andreoni and Miller (1993), as well as Davis and Holt (1993) for a review. Normann and Wallace (forthcoming) show that, except for end-game effects, subjects' cooperative behaviour in a repeated prisoner's dilemma game is unaffected by whether the number of repetitions is finite and known or indefinite.

PROPOSITION 4. *For any SE in Never, there is a SE in After with the same value-contingent payoffs; the reverse, however, is not true.*[14]

Proposition 4 reveals that not all equilibria in *After* can be supported in *Never*. This suggests that cooperation in *Never* is more difficult to maintain. Hence, we would expect lower cooperation in *Never*.

6 Results

We begin this section by comparing cooperation across treatments. In 6.2, we estimate whether a cutoff or the alternating strategy most closely characterises each individual subject's observed decisions. We aim to make sense of our results in 6.3.

6.1 *Cooperation across Treatments*

The left panel of Table 3 offers a simple presentation of aggregate decisions: the entry percentage for a given number and treatment. These summary statistics reveal a number of findings. First, not all subjects play the static Nash equilibrium: exit is the modal decision for the number 1 in both treatments and also for the number 2 in *After*. Strikingly, in *After* when subjects drew the number 1, they entered only 16.3% of the time. Second, the sharp spike in entry percentages in going from the number 2 to 3 in both treatments suggests that many subjects may be employing the socially optimal cutoff of 2.5. Third, that not all subjects are entering all of the time on numbers 4 and 5, particularly in *Never*, suggests the use of alternating strategies for which entry and exit decisions are independent of the numbers received. Finally, cooperation increases with increasing information, as expected and as seen by the overall lower entry frequency in *After*.

[14]Proposition 4 resembles Kandori (1992) who shows that when players' actions are imperfectly observed by partners, as the precision of the signal about a partner's action increases, the set of sequential-equilibrium payoffs expands. In our framework, players' actions are perfectly observable; it is their payoffs from these actions that is private information. We have considered the two extremes of private information (*Never* and *After*). Instead, if players received a noisy signal about their opponents' payoffs after each round, then Proposition 4 would generalise to having the set of SE increase with the precision of the signal, parallel to Kandori.

We estimate a random-effects Probit model to explain the variation in subject i's decision to enter in period t. The specification for our random effects Probit model for each treatment is as follows,[15]

$$\begin{aligned} \widetilde{Enter}_{it} &= constant + \beta_1 * C_{1.5} + \beta_2 * C_{2.5} + \beta_3 * C_{3.5} + \beta_4 * C_{4.5} + \\ & \quad \beta_5 * Enter_{i,t-1} + \beta_6 * Enter_{-i,t-1} + \beta_7 * first10 + \beta_8 * last10 + \epsilon_{it}, \end{aligned} \tag{1}$$

$$\text{where} \quad \epsilon_{it} = \alpha_i + u_{it}$$

$$\text{and} \quad Enter_{it} = \begin{cases} 1 & \text{if } \widetilde{Enter}_{it} \geq 0, \\ 0 & \text{otherwise.} \end{cases}$$

The dummy variable $C_{1.5}$ equals one if player i's period t number is 2, 3, 4 or 5 and equals zero if it is 1; similarly, $C_{2.5}$ equals one for numbers 3, 4 and 5, and zero otherwise, and so forth for $C_{3.5}$ and $C_{4.5}$. The marginal effects of the estimated coefficients on these variables can be interpreted as the marginal propensity to enter for numbers 2, 3, 4 and 5, respectively. Also included in the regression equation are the subject's own last-period entry decision, $Enter_{i,t-1}$, and that of his partner, $Enter_{-i,t-1}$. Finally, we control for initial learning and end-game effects by including dummies for the first 10 and last 10 periods, respectively. The error term, ϵ_{it}, is composed of a random error, u_{it}, and a subject-specific random effect, α_i.

Table 4 displays separately for both treatments the regression coefficients and marginal effects. All of the variables are significant in *After*. In particular, the computed marginal effects displayed in the second column indicate that a subject is 13.9% more likely to enter on a 2 than a 1, 58.7% more likely to enter on a 3 than a 2, 22.1% more likely to enter on a 4 than a 3 and 5.5% more likely to enter on a 5 than a 4. These estimates correspond closely to the differences in percentages of entries by number reported in Table 2, despite the inclusion of a number of other significant controls in the regressions. For instance, the significance of *first10* and *last10* supports initial learning and end-game effects in the anticipated direction: subjects are less likely to enter

[15]The presence of the lagged dependent variable as a regressor renders our estimates inconsistent. To correct for this, we estimated a correlated random effects model (Chamberlain, 1980) in which subject i's first-period entry decision and number were also included as regressors. Because all of the results are qualitatively identical to our random effects Probit results, we report the latter for simplicity.

early on and more likely to enter toward the end of the game. Finally, if a subject entered in the previous round, he is less likely to enter this round, while if his partner entered last round, he is more likely to enter this round. Both of these findings are consistent with reciprocity as well as the pair employing alternating strategies.

The regression results from *Never* are similar, the differences being that the $C_{4.5}$ variable and the initial learning effect captured by "first10" are no longer significant. Not knowing the partner's number and thus his motive for entry and exit, learning requires more time in *Never*.

The estimates of ρ in Table 4 measure the fraction of the error term's variance accounted for by subject-specific variance. The highly significant estimates of 0.395 in *After* and 0.406 in *Never* (both $p < .01$) indicate that about 40% of the variance in the error term is explained by subject heterogeneity.

6.2 *Individual Strategies*

To understand better the heterogeneity in subject behaviour, we infer the strategy that best fits each subject's observed decisions, that is, the strategy that minimises the number of errors in classifying the subject's decisions. We search over each of the possible pure-strategy cutoffs, $c \in \{0.5, 1.5, 2.5, 3.5, 4.5, 5.5\}$, and the alternating strategy, generously modeled as the choice of an action opposite to the one made in the previous round.[16]

Despite the slight payoff advantage and lower payoff variance of the alternating strategy, our main finding is the overwhelming adoption of cooperative cutoff strategies and the paucity of alternators. Table 5 reports the distribution of individuals' best-fit strategies by treatment for rounds 11–70.[17] The optimal symmetric cutoff strategy of $c^* = 2.5$ best characterises the decisions

[16] Although there are other ways to model the alternating strategy, such as enter in odd or even rounds only, our chosen specification based on comparing decisions in rounds t and $t-1$ is robust to mistakes: it detects subjects who began alternating, stopped for one or more rounds and resumed alternating by coordinating differently on who enters on the odd and even rounds.

[17] Excluding the first 10 and last 10 rounds reduces the error rates by minimizing the initial learning and end-game effects documented in the regression analysis. The inferred best-fit strategies are highly robust to the different time horizons tested, like all 80 rounds, the last 60 rounds, the last 40 rounds and rounds 16–65.

of 39/62 subjects in the *After* treatment.[18] Nine subjects in *After* appear to be employing the cutoff of 1.5; for one of these subjects, the static Nash strategy of always enter fits his decisions equally well. Eight additional subjects also play according to the Nash strategy of $c = 0.5$, while four other subjects (two of whom form a pair) use the hyper-cooperative cutoff of 3.5. Only one pair of subjects alternates, beginning in period 33 and continuing without deviation through period 80.

The *Never* treatment is a more likely candidate for alternating because the play of cutoff strategies cannot be observed or enforced. Still, a meager two out of 31 pairs alternate.[19]

Table 5 also reveals a marked shift from higher to lower entry cutoff values in going from *After* to *Never*. For example, the percentage of subjects playing the optimal symmetric pure-strategy cutoff declines from 62.1% in *After* to 38.7% in *Never*, while those who always enter increases from 13.7% to 20.2%. Like the overall entry percentages in Table 3 and the regression results in Table 4, these inferred strategies also point to a decline in cooperation when less information is provided.

Overall, this inference technique fits the data well as seen in the error rates of 6% and 8% for the two treatments, respectively. That is, of the 3720 decisions made by the 62 subjects in *After* between rounds 11 and 70, 3479 of them correspond to the best-fit strategy inferred for each subject. By comparison, if we assume that all subjects are playing the static Nash strategy, then the third-to-last row of data in Table 5 indicates that the error rates jump to 15% and 32% depending on the treatment. In addition, we generated random decisions for subjects calibrating the probability of entry to match the observed overall rate of entry in each treatment (.677 and .744 respectively for the treatments). We then calculated the error rate from these random decisions for each subject's best-fitting strategy and for each subject assuming static Nash play. The results in the bottom two rows of Table 5 again demonstrate that our inferred

[18] In the case where two strategies explain a subject's decisions equally well, each of the tied strategies receives half a point.

[19] For these pairs, alternation begins in rounds 2 and 8, respectively, and continues flawlessly for the duration. An additional subject whose best-fit strategy is alternating eventually abandons it after his partner fails to reciprocate.

strategies on the actual data fit the data much better than the best-fitting and Nash strategies on the randomly generated data. In sum, subjects play in a non-random, methodic fashion that, for the vast majority, can be captured by cutoff strategies.[20]

Our strategy analysis also reveals that pair members typically coordinate on the same cooperative strategy. In *After*, of the 30 pairs that employ cutoff strategies, partners in 22 pairs coordinate on the same cutoff values. If subjects independently chose their strategies according to the observed distribution of best-fit strategies, the probability of at least 22 pairs coordinating on the same cutoff is 1/60. Sixteen out of 28 pairs coordinate within the pair on the same cutoff in *Never*. In addition, for all 12 pairs that do not, the partners' inferred cutoffs differ by only one integer value. Again, if subjects drew their strategies independently from the observed distribution, the likelihood of obtaining this degree of coordination or better is 1/600. The implication is that it is extremely unlikely in *After* and in *Never* that paired subjects achieved the observed degree of coordination on the same or similar cutoff values by mere chance. Paired subjects' coordination is particularly surprising in *Never*, since partners' values are unobservable.

Successful coordination on the same strategy shows up in the form of higher profits for subjects playing the optimal cooperative cutoff strategy than those who always enter. The right-hand columns of each treatment in Table 5 reveal that the average subject profits for c^*=2.5 are 111.6 and 106.8 in *After* and *Never*, respectively, compared to 109.5 and 93.2 for always enter.

6.3 *Why so few alternators?*

Despite alternation's higher expected payoff and lower payoff variance, and the unobservability of cutoffs in *Never* and their difficulty to observe outside the laboratory, the overwhelming majority of subjects in both treatments employ cooperative cutoffs. There are two possible explanations.

First, alternation is a form of conditional cooperation;[21] its success requires coordination on

[20] A complementary method to determine subjects' strategies is to ask them. We did this in a post-experiment questionnaire. Many subjects claim to decide randomly when in fact their decisions display a clear tendency to enter on higher numbers and exit on lower ones. For the minority of subjects whose responses are interpretable as either alternating or cutoffs, they match our inferred strategies well.

[21] See Keser and van Winden (2000) for evidence and an analysis of conditional cooperation in public goods

the part of both pair members. Several subjects began the game alternating, but abandoned it soon after their partner failed to reciprocate. By contrast, cutoff cooperation can be implemented unilaterally and its usefulness does not require coordination on the same cutoff.

Second, cutoff cooperation is cheap, since it involves exiting on the lowest values, when it is least costly to do so; whereas, alternation ignores the value to entry. Thus, a player who chooses to cooperate regardless of whether his partner reciprocates foregoes less profit from exiting only on low values than if he exits just as often without regard for values (as with alternating).

To determine which of these reasons accounts for subjects' unwillingness to alternate, we designed an additional pair of treatments that maintains the difficulty of coordinating jointly on the alternating strategy, but makes cutoff cooperation less cheap.

7 In Search of Alternating

7.1 *Experimental Game and Procedures*

By shrinking the percentage difference between $\underline{v}$ and $\overline{v}$, the values to entering become more alike making cutoff cooperation less cheap. To achieve this, we conducted two additional treatments in which we added a constant of 100 to the randomly drawn numbers 1-5. The *After100* and *Never100* treatments are identical to the similarly named original treatments (e.g., five integers in the range), except that players' *iid* integers come from the uniform distribution 101 to 105. The dominant stage-game strategy remains entry.[22] The socially optimal cutoff, $c^* = 101.5$, involves exiting only on the lowest integer in the range (as opposed to the two lowest integers in the original treatments) and yields the pair an expected payoff of 77.28 units per round. By comparison, alternating earns 103 in expectation, a 33% premium over $c^* = 101.5$. The research question can thus be phrased as: is the joint payoff premium to alternation sufficient to overcome its inherent dual coordination problem?

game experiments.

[22]Note that the payoff to exit remains zero. If we had also added 100 to the exit payoff, entry would no longer be the dominant strategy.

Sixty and 70 subjects participated in *After100* and *Never100*, respectively. Participation was again restricted to one experiment per subject and no subject had participated in either *After* or *Never*. In selecting the experimental-currency-to-shekel ratio, we held constant across both sets of treatments the joint monetary payoff from the optimal cooperative strategy of alternating. Also, keeping fixed his partner's decisions, a player always entering earns the same expected monetary payoff in all four treatments.

7.2 *Results from Follow-Up Treatments*

The right panel of Table 3 reveals that roughly 61% of the decisions are enter on 101 in *After100* and *Never100*, increasing to just 67% on the number 105. This stability of entry percentages attests to alternation. The strategy inference analysis in Table 6 confirms the preponderance of alternators: alternating is the best-fit strategy for 64% of subjects in *Never100* and a still higher 73% of subjects in *After100*, even though *After100* affords the opportunity to observe and thus coordinate on cooperative cutoff strategies. Alternating and Nash play account for about 95% of subjects in both treatments. No subject plays according to the optimal cutoff $c^* = 101.5$ in *After100* and only 1.5/70 adopt this cutoff in *Never100*. Put starkly, those who cooperate in these experiments alternate; the remaining quarter of the subjects are best described by entering in every round.

How can we explain the shift from almost all cutoff cooperators in the original treatments to almost all alternators in these follow-up treatments? By adding a constant of 100, both the nominal and real payoffs to entry are made similar for all values 101-105. It no longer matters substantively whether a player enters alone on the highest or lowest integer: the difference in both monetary and nominal terms between the two outcomes is a paltry 4% compared to 400% in the original treatments. In addition, exiting on the lowest integer is now about three times costlier than in the original treatments, no matter if only one player exits (foregone real profit of 0.588 vs. 0.2) or both do (foregone real profit of 1.765 vs. 0.6). Alternation ensures that exactly one player enters each round, thereby at once avoiding congestion and the now costlier outcome whereby both players receive low draws and exit.

The prevalence of alternators in these treatments implies that the two-person coordination problem inherent in alternating is not insurmountable. By increasing the joint-expected-payoff advantage to alternating (i.e., by making cutoff cooperation less cheap), all cooperators switch from cutoffs to taking turns.

Figures 1a and 1b also attest to the pervasiveness and stability over time of the alternating strategy in both *After100* and *Never100.* If all subjects employed the alternating strategy throughout the game, 50% of the decisions would be exit in every round; whereas exit percentages varying from 0 to 100 depending on the numbers drawn would reflect cooperative cutoff strategies. In round 3, for example, paired subjects drew numbers 101 and 102 followed by 104 and 105 in round 4. Accordingly, the exit percentage swung from 57% to 17% in *Never100* and from 48% to 23% in *After100*, suggesting that some subjects are using cooperative cutoffs in these early rounds. In *After100*, from round 17 through round 78, the percentage of exit decisions stabilises at about 40%, despite the randomly drawn numbers each round. In *Never100*, the percentage of exit decisions starts below 30% and it is not until round 40 that it reaches 40% where it stabilises, again until the second-to-last round.[23]

It is counterintuitive that *After100* reveals a higher percentage of alternating pairs and their faster formation than *Never100* in which alternating is the only verifiable cooperative strategy.

How does revealing one's number at the end of the round facilitate the formation of alternating pairs, even though alternating in no way depends on the subject's number? The answer lies in the fact that *After* makes one's strategy more transparent. Cooperators in *After100* are able to coordinate quickly on alternation upon discerning the pattern in a partner's decisions combined with his revealed numbers. For example, a subject in *After100* who exits on a 105 in one round while entering on a 101 in the next sends a strong signal that he is not playing a cutoff strategy. *Never100* offers no such conspicuous opportunity to communicate one's intentions due to the unobservability of the partner's number.[24]

[23]The relatively high error rate of the best-fit strategies of 0.13 in *Never100* compared to only 0.06 in *After100* also reflects the extra time required to converge on alternating in *Never100.*

[24]Two car salespersons working in the same dealership provide a rough illustration of the usefulness of learning each others' values for coordinating on alternation. From across one's desk, one can observe the client's reaction

The other striking observation from these time series of exit decisions is the sudden drop off in exiting in the final two rounds. In *After100*, from around 40% of all decisions in rounds 17-78, exit decisions plummet to 23% and 5% in rounds 79 and 80, respectively. Similarly, in *Never100*, exit decisions shrink to 26% and 7% in the last two rounds after having stabilised at around 40% during the last half of the game. Like the endgame effects observed in the original treatments, these sharp declines in cooperative behaviour in the final two rounds suggest that cooperation throughout the game is at least in some measure strategic.

8 Lessons for Cooperation Outside the Laboratory

Cooperation assumes many forms outside the laboratory. Two such forms are alternation whereby players take turns and cutoff strategies whereby private values determine actions. We design a game that permits both of these forms of cooperation. Moreover, both modes of cooperation can be supported as equilibria in the infinitely repeated game. Similar to other finitely repeated social dilemmas, subjects play our finitely repeated game (with a known terminal round of 80) cooperatively in a manner consistent with these equilibria. Our results thus provide criteria for selecting cutoff cooperation and alternation.

In real-world cooperation dilemmas, when the skill required for the task varies little across individuals, participants' values tend to be alike and hence, according to our results, alternation is adopted. Similar values are likely if the task requires either low skill which all possess (mundane) or high skill but individuals are equally skilled at the task. By contrast, individuals' values are diffuse for tasks that call for a particular skill that not all individuals possess equally or tasks that elicit a strong heterogeneity in preferences. In these situations, cooperative participants will adopt cutoff strategies, even if alternation yields similar expected payoffs. For participants to overcome the costly two-person coordination required of alternation, it must

to the other salesperson and ultimately whether the other salesperson made the sale, the value of the sale and the time it took. Over the course of time, the salespersons learn which of them has a comparative advantage with which types of customers (based on the latter's visible characteristics) and divide up customers accordingly.

provide a substantially higher payoff than cutoff strategies.[25]

Several examples highlight these distinctions. Construction companies that compete regularly in procurement auctions may have similar values for winning contracts if the firms share similar cost structures and expertise, as may be the case in mature industries. On the other hand, their values may diverge substantially if their costs differ due to, for example, different firm specializations or one firm not having adequate idle capacity to complete the contract work. Such firm asymmetries may well be observable to industry experts and antitrust authorities. To the extent that bidders are able to collude tacitly, the former scenario predicts firms taking turns bidding in alternate auctions, while the latter scenario predicts the adoption of cutoff strategies. Thus, where cooperation is illegal and thus not flaunted by colluding firms, industry structure can serve to alert antitrust authorities as to which type of collusion to anticipate.

Cabdrivers working for the same cab company are assigned to passengers in two distinct ways. Similar to alternating, cabdrivers at a taxistand serve passengers in a predetermined order based on the observable time at which the drivers returned to the stand. This solution distributes passengers evenly and prevents conflict between cabbies, all of whom are available with identical locations. However, for passengers who call the cab company, such an assignment would be inefficient and likely elicit complaints from passengers and from the cabbies dispersed throughout the city. Instead, the dispatcher broadcasts the location of the passenger and allows cabdrivers to take advantage of their private information (e.g., availability, distance to the customer) to divide up customers according to their values, similar to cutoff strategies.[26]

Likewise, an army sergeant, committee of commune members, shift manager or head of a team of programmers may assign mundane tasks (e.g., cleaning the latrine, unpopular shifts, routine programming) using a duty roster or other system that disregards input from group members (alternating); or, in the case of diverse values (e.g., combat duty, revenue-generating activities for

[25]While these insights focus on the game's structure for equilibrium selection, endogenous factors such as history, expectations and leadership might also influence the choice of cooperative outcome (see Acemoglu and Jackson, 2011).

[26]Similarly, Burks et al. (2009) note that bicycle couriers receive assignments either directly from the dispatcher (allocated dispatch) or from a free call system whereby the courier who first responds to the call makes the pickup.

the commune, choice shifts, challenging programming), these same authority figures may allow members to self-select their tasks based on privately known ability and preferences (cutoffs).

In short, each cooperative strategy has its place and time. Allowing members to choose their tasks exploits their private information. By the same token, conflict may ensue if more than one member opts for the same task, while other unwanted tasks may remain unfilled. Alternation assigns exactly one member to each task, thus at once avoiding conflict and ensuring that no opportunity is missed.

Appendix A - Proofs of Propositions

Proof of Proposition 1: Suppose the cooperative solution entails entering on the number x_1. This implies that the joint expected payoff to entering on x_1 is greater than the joint expected payoff to staying out,

$$\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y\Big[\big(1-p(y)\big)x_1 + p(y)\big(f(x_1,y)+f(y,x_1)\big)\Big] \geq \sum_{y\in\{\underline{v},...,\overline{v}\}} \pi_y y\, p(y).$$

If $x_2 > x_1$, then,

$$\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y\Big[\big(1-p(y)\big)x_2 + p(y)\big(f(x_2,y)+f(y,x_2)\big)\Big]$$

$$= \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y(x_2-x_1)\big(1-p(y)\big) + \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y\Big[\big(1-p(y)\big)x_1 + p(y)\big(f(x_2,y)+f(y,x_2)\big)\Big].$$

If there is a y such that $p(y) > 0$, since f is strictly increasing in at least one argument and $x_2 > x_1$, we have,

$$\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y(x_2-x_1)\big(1-p(y)\big) + \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y\Big[\big(1-p(y)\big)x_1 + p(y)\big(f(x_2,y)+f(y,x_2)\big)\Big]$$

$$> \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y(x_2-x_1)\big(1-p(y)\big) + \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y\Big[\big(1-p(y)\big)x_1 + p(y)\big(f(x_1,y)+f(y,x_1)\big)\Big]$$

$$\geq \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y\Big[\big(1-p(y)\big)x_1 + p(y)\big(f(x_1,y)+f(y,x_1)\big)\Big].$$

Otherwise $p(y) = 0$ for all y and since $x_2 > x_1$, we have $\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y (x_2 - x_1)\big(1 - p(y)\big) > 0$. Thus,

$$\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y (x_2 - x_1)\big(1 - p(y)\big) + \sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y \Big[\big(1 - p(y)\big) \cdot x_1 + p(y)\big(f(x_2, y) + f(y, x_2)\big)\Big] >$$

$$\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y \Big[\big(1 - p(y)\big)x_1 + p(y)\big(f(x_1, y) + f(y, x_1)\big)\Big].$$

Since $\sum_{y\in\{\underline{v},...,\overline{v}\}} \pi_y y\, p(y)$ does not depend upon x_1 or x_2, we have,

$$\sum_{y\in\{\underline{v}...\overline{v}\}} \pi_y \Big[\big(1 - p(y)\big)x_2 + p(y)\big(f(x_2, y) + f(y, x_2)\big)\Big] > \sum_{y\in\{\underline{v},...,\overline{v}\}} \pi_y y\, p(y). \square$$

PROPOSITION A1. *The socially optimal pure-strategy symmetric cutoff for integers drawn independently from the uniform distribution of integers from* $\underline{v}$ *to* $\overline{v}$ *and congestion parameter* k *is given by,*

$$c^* = \frac{-1 - 2\,\overline{v} + (2\,\underline{v} - 1)\;k + \sqrt{12\,\overline{v}\;(1 + \overline{v})\;(k - 1)^2 + (1 + 2\,\overline{v} + k - 2\,\underline{v}\,k)^2}}{6\;(k - 1)}.$$

Proof of Proposition A1: Let us examine the costs and benefits of extending the symmetric cutoff by one from $c - 1/2$ to $c + 1/2$. We can represent the problem on a grid that is $\overline{v} - \underline{v} + 1$ units by $\overline{v} - \underline{v} + 1$ units. Each point on the grid refers to the net gains if the numbers drawn are from that point. The uniform independent distribution implies that each grid point has equal weight. Let us refer to each point as (x, y). The points affected are $(\cdot, c)$ and $(c, \cdot)$. Divide this set of points into three groups. Group one is (c, z) and (z, c) where $z > c$. Group two is (c, z) and (z, c) where $z < c$. Group three is (c, c).

For each grid point in group one, there is a net gain of $z - (z + c)/k$. For group two, there is a net loss of c for each grid point. For group three, there is a net loss of $2c/k$. For all of the points together, there is a net gain of,

$$\underbrace{2\sum_{z=c+1}^{\overline{v}}(z - \frac{z+c}{k})}_{\text{Group 1}} - \underbrace{c \cdot 2(c - \underline{v})}_{\text{Group 2}} - \underbrace{2\frac{c}{k}}_{\text{Group 3}} = \frac{\overline{v}\;(1 + \overline{v})\;(k - 1) - (1 + 2\,\overline{v} + k - 2\,\underline{v}\,k)\;c - 3\;(k - 1)\;c^2}{k}.$$

This is simply a quadratic with both a positive and a negative root. The expression represents the net benefit of increasing the pure-strategy cutoff c starting at $\underline{v}$. It will eventually become negative as c surpasses the positive root c^*. Thus, for pure strategies, the positive root provides the optimal cutoff where exiting occurs if and only if one's number is below c^*. From Proposition 1, the optimal cutoff strategy *may* entail the use of mixed strategies. While we don't do so here, the optimal mixed strategy can be derived in the same manner. $\square$

Although the expression for c^* seems unintuitive, it demonstrates the uniqueness of the socially optimal cutoff and leads to some sensible comparative-statics results. First, as the congestion parameter, k, increases, so does the optimal symmetric cutoff for a given $\underline{v}$ and $\overline{v}$. Intuitively, as k increases, it becomes increasingly costly for both players to enter; as a result, the socially optimal threshold for entry increases. Moreover, taking k and $\underline{v}$ as fixed, the expression for c^* also reveals that as $\overline{v}$ increases, so does the socially optimal cutoff.

Corollary A2: *For integer numbers uniformly distributed on* $[\underline{v}, \overline{v}]$, $\underline{v} < \overline{v}$, *and* $k \geq 3$, *the socially optimal cutoff always involves each player exiting on at least the integer* $\underline{v}$.

Proof of Corollary A2: The two comparative-statics results preceding the corollary indicate that the most difficult test for the corollary is $k = 3$ and the range of integers $[\underline{v}, \underline{v} + 1]$. If we can show that the socially optimal strategy is exit on $\underline{v}$ for this case, then the corollary holds for all $\overline{v} > \underline{v}$ and $k \geq 3$. Each player earns in expectation $(\frac{\underline{v}}{2} + \frac{\underline{v}+1}{2}) \cdot \frac{1}{3} = \frac{2\underline{v}+1}{6}$ if he enters on both $\underline{v}$ and $\underline{v} + 1$. But by staying out on $\underline{v}$, each player does better with expected earnings equal to $\frac{\underline{v}+1}{2} \cdot (\frac{1}{2} + \frac{1}{2} \cdot \frac{1}{3}) = \frac{2\underline{v}+2}{6}$. $\square$

Proof of Proposition 2: Independent of k, alternating yields a joint expected payoff equal to the expected value of the range of numbers, while the joint expected payoff of any symmetric cutoff strategy (strictly less than $\overline{v}$) is strictly decreasing in k. Consider the case of $k = 2$. The strategy of always enter (the lowest possible cutoff) yields half the expected value for each player. Thus, for $k = 2$, the joint expected payoffs are the same for alternating and always entering. Hence, for $k < 2$, the joint expected payoff from the not necessarily optimal cutoff strategy of always enter will be strictly higher than that of alternating, implying that the optimal cutoff will yield expected payoffs that are strictly higher as well.

For the uniform distribution and $k \to \infty$, using the grid method of the previous proof, alternating yields $(\overline{v} - \underline{v} + 1) \sum_{z=\underline{v}}^{\overline{v}} z = (1 + \overline{v} - \underline{v})^2(\underline{v} + \overline{v})/2$. As $k \to \infty$, both players entering yields a payoff of 0 (as does both exiting). This simplifies the joint-payoff calculation of the cutoff strategy c^* to $2(c^* - \underline{v}) \sum_{z=c^*}^{\overline{v}} z = (1 + \overline{v} - c^*)(c^* - \underline{v})(\overline{v} + c^*)$. The expression $(1 + \overline{v} - c^*)(c^* - \underline{v})$ reaches its maximum at $c^* = (1 + \underline{v} + \overline{v})/2$, yielding $(1 + \overline{v} - \underline{v})^2/4$. Since $(\overline{v} + c^*)$ is maximised for $c^* = \overline{v}$, we know the joint cutoff payoff must be strictly less than $(1 + \overline{v} - \underline{v})^2 \cdot \overline{v}/2$. For $\underline{v} > 0$, this is less than the joint alternating payoff. $\square$

Proof of Proposition 3: (i) Assume that a deviation from the intended strategy prompts the opponent to enter forever after (grim trigger strategy). Such a deviation from alternation is done by entering out of turn and always detected in either the *After* or *Never* treatments. The payoff to deviating from alternation is highest on a 5 and yields an expected payoff of, $\frac{5}{3} + 1 \cdot \frac{\delta}{1-\delta}$, whereas continued alternation yields an expected payoff of $3\delta + 3\delta^3 + \ldots = \frac{3\delta}{1-\delta^2}$. Thus, a player will never deviate from alternation if and only if $\frac{3\delta}{1-\delta^2} \geq \frac{5}{3} + \frac{\delta}{1-\delta}$, or $\delta \geq 0.679$. For infinitely repeated, complete-information, symmetric 2x2 games, see Lau and Mui (forthcoming) for a general solution of alternating as an equilibrium strategy.

(ii) Again assuming a trigger-strategy punishment, we now verify that each of the cooperative cutoffs $c = 1.5$, $c^* = 2.5$ and $c = 3.5$ constitutes a symmetric SE for a sufficiently high δ. For each of these cutoff strategies, the most profitable deviation involves entering on the highest value below the cutoff, namely, entering on $c - 0.5$. The expected present discounted deviation payoff is thus, $(c - 0.5)(1 - p) + \frac{c-0.5}{3}p + \frac{\delta}{1-\delta}$, where p is the probability that the opponent also enters in the deviation round, equal to 0.8, 0.6 and 0.4 when $c = 1.5$, $c^* = 2.5$ and $c = 3.5$, respectively. The expected present discounted payoff from $c = 1.5$, $c^* = 2.5$ and $c = 3.5$ for the infinitely repeated game are $\frac{1.305 \cdot \delta}{1-\delta}$, $\frac{1.44 \cdot \delta}{1-\delta}$ and $\frac{1.32 \cdot \delta}{1-\delta}$, respectively. Comparing each of these expressions with the corresponding deviation payoff implies that a player never deviates as long as $\delta \geq 0.605$ for $c = 1.5$, $\delta \geq 0.732$ for $c^* = 2.5$, and $\delta \geq 0.873$ for $c = 3.5$. In addition, the cooperative cutoffs 4.5 and 5.5 cannot be supported as symmetric SE since they yield lower stage-game joint expected payoffs than always enter (see Table 1).

In *Never*, these symmetric cooperative cutoffs cannot form an equilibrium strategy. Consider the following two sets of realizations of infinite sequences of random values, $\{x, y\}$ and $\{x^{'}, y^{'}\}$. For both sequences, player 1 has the exact same realizations, $x = x^{'}$. Player 2's realizations differ in round t only: in one sequence he draws a 5, $y_t = 5$, while in the other he draws a 1, $y_t^{'} = 1$. In all other rounds $s \neq t$, we have $y_s = y_s^{'}$. When $y_t^{'} = 1$, we have shown that the equilibrium strategy in *After* involves exiting, since entry triggers player 1's punishment strategy. In *Never*, the two sequences $\{x, y\}$ and $\{x^{'}, y^{'}\}$ are indistinguishable to player 1 so that play by a cutoff strategy dictates the same actions for player 1. Hence, if player 2 plays as if he drew sequence y when in fact he faces sequence $y^{'}$, player 2 profits from this deviation simply because player 1 behaves exactly as if player 1 drew sequence y.

(iii) In part (ii) we already established that non-history dependent cutoff cooperation is not sustainable. Here we establish that a form of cutoff cooperation is indeed possible. Consider the cooperative strategy of exiting one out of every two rounds. Let us assume that as opposed to alternating, this is done solely by cutoffs. For example, on a 1 or 2 in the first round, a player stays out in the first round and enters in the second. On a 3, 4 or 5, a player enters in the first round and stays out in the second. This gives a two-round expected payoff of $0.6 \cdot (4 \cdot 0.4 + 4/3 \cdot 0.6) + 0.4\delta \cdot (3 \cdot 0.6 + 1 \cdot 0.4) = 1.44 + 0.88\delta$. Let us again assume trigger-strategy punishment. The highest incentive to deviate occurs when one player draws a 5 in the second round, but knows that both players are supposed to stay out in that round. The payoff to deviating is $5 + \frac{\delta}{1-\delta}$. The payoff for staying the course is $\frac{\delta(1.44+0.88\delta)}{1-\delta^2}$. Cooperation can be established if $\delta > 0.968$. $\square$

Proof of Proposition 4: Any SE in *Never* for which the equilibrium strategies are contingent on observables can be exactly duplicated in *After*. What if the equilibrium strategies in *Never* condition on player i's own value, which is unobservable to the opponent? We will show that for these equilibria, there are comparable, isomorphic equilibria in *After* in which the player's value-contingent strategy can be replaced with a value-independent strategy that attains the same expected action profile and the other player chooses the same strategy as in *Never*; as a result, both players earn the same expected payoffs as in *Never*.

Consider player i's strategy in period t denoted by $s_{it}(v^{t-1}, v_{it}, a^{t-1})$, where v^t and a^t are the histories of all values and actions, respectively, up to period t. In *Never*, since the opponent's values are never revealed, a player's strategy can condition on his own values only, $s_{it}(v_i^t, a^{t-1})$. In *Never*, player i's present and future payoffs depend on his previous values only insofar as they affect his individual strategy. This is because his period payoff is $u_i(v_{it}, a_{it}, a_{jt})$, $j \neq i$, and only his actions can depend upon previous values. In *After*, the opponent's j's action can also depend on player i's values, $i \neq j$.

For any *Never* equilibrium in which player i's strategy depends upon his previous values, there exists another equilibrium that yields the same expected payoffs for both players where player i's strategy does not depend upon his previous values and the other player employs the same strategies as in the initial equilibrium. This holds because player i must be indifferent between his value-dependent strategy and one that isn't dependent on previous values that mixes with the same action probabilities, that is, $P(a_{it} = A \mid a^{t-1}, v_{it})$ is the same for both strategies. This value-independent strategy must be an equilibrium since it does not affect the other player's expected payoffs. These same value-independent strategies form an equilibrium in *After*. □

We illustrate this equivalence with an example. Suppose the history a^{t-1} in which $a_{it-1} =$ *enter* forms part of an equilibrium in *Never*. Suppose also that player i enters in round t for v_{it} equal to 4 or 5, and enters on value 3 if and only if $v_{it-1} = 4$. An equivalent equilibrium strategy for this period would be to enter on a 3 with probability $P(a_{it} = \textit{enter} \mid a^{t-1}, v_{it-1} = 4) \equiv 1/3$. Applying this to both players in all periods generates an equilibrium based on observables in both *Never* and *After*.

The fact that the symmetric cutoff of $c^* = 2.5$ can be a SE in *After* (Proposition 3 (ii)) but not in *Never* serves as a counterexample to establish the second part of the proposition, namely, that not all SE in *After* are also in *Never*.

Appendix B - Participants' Instructions

After treatment, translated from the original Hebrew

The experiment in which you will participate involves the study of decision-making. The instructions are simple. If you follow them carefully and make wise decisions, you may earn a considerable amount of money. Your earnings depend on your decisions. All of your decisions will remain anonymous and will be collected through a computer network. Your choices are to be made at the computer at which you are seated. Your earnings will be revealed to you as they accumulate during the course of the experiment. Your total earnings will be paid to you, in cash, at the end of the experiment.

There are several experiments of the same type taking place at the same time in this room.

This experiment consists of 80 rounds. You will be paired with another person. This person will remain the same for all 80 rounds. Each round consists of the following sequence of events. At the beginning of the round, you and the person with whom you are paired each receives a randomly and independently drawn integer number from 1 to 5 inclusive. This number is your private information, that is, the other person will not see your number and you will not see the other person's number. After each of you sees your own number, you must each decide separately between one of two actions: enter or exit. At the end of each round, your number, your action, and the other person's action determine your round profit in the following way. If you both chose to exit, then you both receive zero points. If you chose to exit and the other person chose to enter, then you receive zero points and the other person receives points equal to his number. On the other hand, if you chose to enter and the other person chose to exit, you receive points equal to your number and the other person receives zero points. If you both chose to enter, then you receive points equal to one-third of your number and the other person receives points equal to one-third of his number. The table below summarises the payoff structure.

Suppose you receive a number, x, and the other person receives a number, y. The round profits for each of the given pair of decisions are indicated in the table below. The number preceding the comma refers to your round profit; the number after the comma is the other person's round profit.

After you have both made your decisions for the round, you will see the amount of points you have earned for the round, the other person's decision and his number. When you are ready to begin the next round, press Next.

At the end of the experiment, you will be paid your accumulated earnings from the experiment

		Other Person	
		Enter	Exit
You	Enter	x/3, y/3	x, 0
	Exit	0, y	0, 0

in cash. While the earnings are being counted, you will be asked to complete a questionnaire. Prior to the beginning of the experiment, you will partake in a number of practice rounds. The rules of the practice rounds are identical to those of the experiment in which you will participate. Note well that for the purpose of the practice rounds, you will be paired with a different person from the actual experiment. The purpose of the practice rounds is to familiarise you with the rules of the experiment and the computer interface. The profits earned in these practice rounds will not be included in your payment. If you have any questions, raise your hand and a monitor will assist you. It is important that you understand the instructions. Misunderstandings can result in losses in profit.

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Table 1
2x2 Payoff Matrix for Standard Cooperation and Coordination Games

	cooperate/exit	defect/enter
cooperate/exit	a, a	0, 1
defect/enter	1, 0	b, b

our game	: $1/2 > b > a = 0$
prisoners' dilemma/public goods	: $a > b > 0$, $1 > a > 1/2$
threshold public goods	: $1/2 > a > 0 > b$
market-entry game	: $a = 0 > b$
chicken	: $1 > a > 0 > b$
battle of the sexes	: $a, b > 1$

Table 2
Joint expected payoff for each cutoff strategy and alternating

Strategy	Joint Expected Payoff
c=0.5 (always Enter)	2
c=1.5	2.61
c*=2.5	2.88
c=3.5	2.64
c=4.5	1.73
c=5.5 (always Exit)	0
Alternating	3

The pair's joint expected payoff for each symmetric pure-strategy cutoff and alternating.

Table 3
Entry by Number and by Treatment

Number	*After*	*Never*
1	16.3%	30.8%
2	29.4%	53.8%
3	86.2%	88.8%
4	98.0%	95.6%
5	98.5%	95.4%
Overall	67.7%	74.4%

Number	*After100*	*Never100*
101	62.6%	60.0%
102	58.9%	61.1%
103	63.1%	67.1%
104	65.6%	67.2%
105	65.7%	67.8%
Overall	63.3%	64.8%

For each number, each cell shows the entry percentage across all subjects in the treatment. The left panel displays the original *After* and *Never* treatments. The right panel displays the follow-up *After100* and *Never100* treatments.

Table 4 - Random Effects Probit Regressions for Entry Decisions from both treatments

Variable	After		Never	
	coefficient (std. error)	marginal effect	coefficient (std. error)	marginal effect
$C_{1.5}$	0.513*** (0.079)	0.139	0.790*** (0.070)	0.210
$C_{2.5}$	2.161*** (0.081)	0.587	1.522*** (0.083)	0.377
$C_{3.5}$	1.039*** (0.112)	0.221	0.653*** (0.105)	0.129
$C_{4.5}$	0.257* (0.156)	0.055	0.025 (0.118)	0.000
$Enter_{i,t-1}$	-0.257*** (0.065)	-0.078	-0.734*** (0.066)	-0.124
$Enter_{-i,t-1}$	0.356*** (0.065)	0.088	0.563*** (0.064)	0.135
first10	-0.246*** (0.089)	-0.062	-0.123 (0.082)	0.000
last10	0.563*** (0.091)	0.103	0.542*** (0.086)	0.088
constant	-1.247 (0.104)		-0.655 (0.106)	
Number of Obs.	4898		4898	
ρ	0.395 (0.031)		0.406 (0.029)	
Log L	-1244.3		-1486.3	

The dependent variable is subject *i* 's entry decision in period *t* .
*** p-value less than .01 ** p-value less than .05 * p-value less than .10

Random effects Probit regression results from pooled data from both treatments. The entry decision of subject *i* in period *t* is regressed on dummy variables for the numbers received, the subject's and his opponent's last period entry decision, and the first and last 10 rounds of play.

Table 5

Strategy Inference Results by Treatment

	Strategy	Treatment					
		After			*Never*		
		number	(fraction)	ave. profit	number	(fraction)	ave. profit
	c=0.5 (always Enter)	8.5	(.137)	109.5	12.5	(.202)	93.2
	c*=1.5	9	(.145)	98.7	19.5	(.315)	110.4
	c=2.5	38.5	(.621)	111.6	24	(.387)	106.8
	c=3.5	4	(.065)	110.0	1	(.016)	110.0
	c=4.5	0	---		0	---	---
	c=5.5 (always Exit)	0	---		0	---	---
	Opposite Previous Round	2	(.032)	117.3	5	(.081)	112.1
	Total	62	(1)	109.5	62	(1)	105.7
	experimental data						
	best-fitting strategies		0.06			0.08	
probability	Nash equilibrium strategy		0.32			0.26	
of error	randomly generated data						
	best-fitting strategies		0.31			0.24	
	Nash equilibrium strategy		0.32			0.24	

Number (fraction) of subjects whose best-fit strategy based on their decisions from rounds 11-70 corresponds to the one indicated and the average nominal profit earned by subjects playing each strategy type. The average error rates from classifying subjects according to these inferred strategies and from the assumption that all subjects play the Nash equilibrium are shown along with the average error rates for randomly generated data.

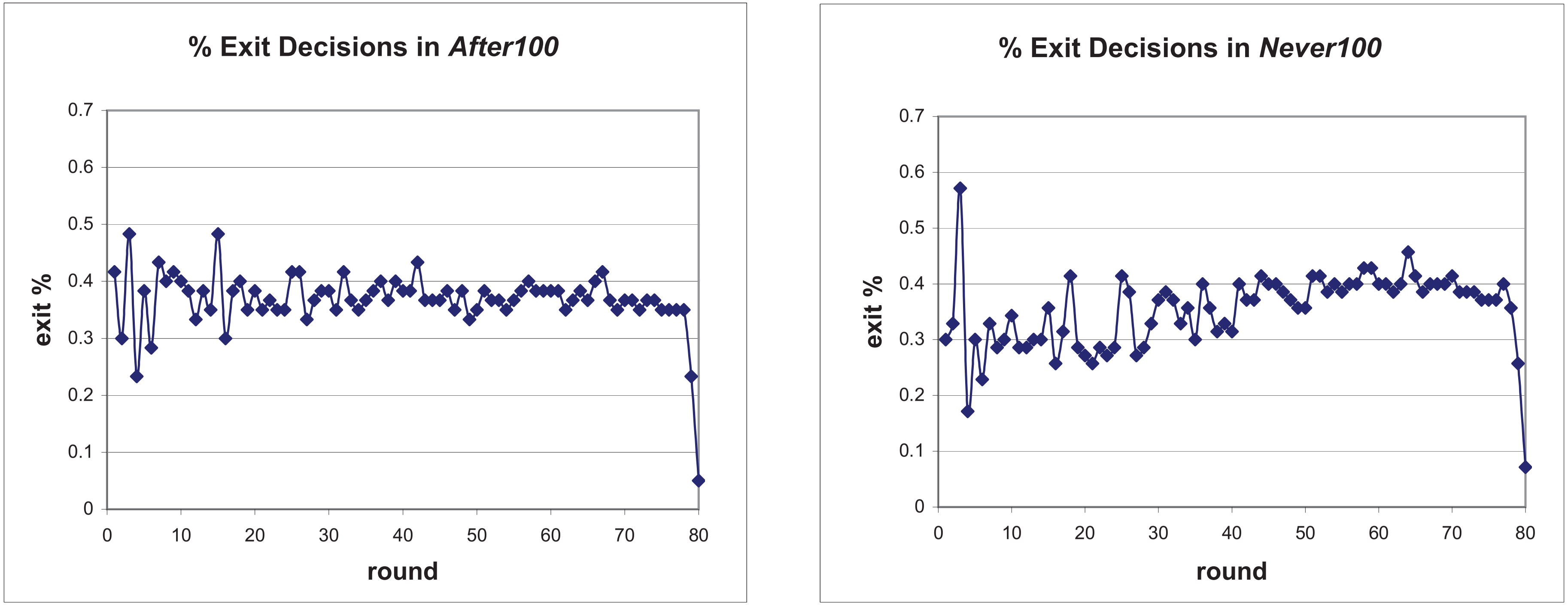
Table 6

Strategy Inference Results (Treatments with Constant of 100 Added to Entry Values)

	Strategy	Treatment					
		After100			*Never100*		
		number	(fraction)	ave. profit	number	(fraction)	ave. profit
	c=100.5 (always Enter)	14	(.233)	2885	21.5	(.307)	3166
	c*=101.5	0	---	---	1.5	(.021)	3596
	c=102.5	2	(.033)	3397	2.5	(.036)	3375
	c=103.5	0	---	---	0	---	---
	c=104.5	0	---	---	0	---	---
	c=105.5 (always Exit)	0	---	---	0	---	---
	Opposite Previous Round	44	(.733)	3945	44.5	(.636)	3853
	Total	60	(1)	3679	70	(1)	3619
probability of error	experimental data						
	best-fitting strategies	0.06			0.13		
	Nash equilibrium strategy	0.37			0.36		
	randomly generated data						
	best-fitting strategies	0.37			0.36		
	Nash equilibrium strategy	0.38			0.37		

Number (fraction) of subjects whose best-fit strategy based on their decisions from rounds 11-70 corresponds to the one indicated and the average nominal profit earned by subjects playing each strategy type. The average error rates from classifying subjects according to these inferred strategies and from the assumption that all subjects play the Nash equilibrium are shown along with the average error rates for randomly generated data.

Figures 1a and 1b



The percentage of exit decisions by round pooled across all subjects for the *After100* (left panel) and *Never100* (right panel) treatments.