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How Fairness Can Affect Voluntary Contributions to Public Goods

*Stephane Aymard**

I. Introduction

Contributions to public goods have been studied experimentally by economists and sociologists for a long time. The main result is that subjects free ride, but not as much as game theory predicts. The standard game is as follows. Each member of a group of *n* players receives an endowment z_i. Each player has to choose how much to invest in a public good, i.e., a contribution $t_i \leq z_i$. The experimenter collects the contributions, multiplies the total $T = \Sigma t_i$ by a and divides equally the product among the players. Thus, the utility of a player is $u_I = z_I - t_I + aT/n$. The game-theoretic prediction is that no one contributes as long as $a/n < 1$. Experimental results showed that this prediction is not verified: subjects contribute around 40% of their endowments (see Ledyard, 1995, for a survey). The main studies focused on the rate of return of the public good, the number of players, the introduction of thresholds, institutional rules, etc. Some of them also examined subjects' preferences: comparative studies have been done on gender or education (for instance, Brown-Kruse and Hummels, 1992). In this paper, we propose to test the influence of fairness on subjects' decisions. Previous studies used questionnaires to discriminate among participants those who have stronger senses of fairness. Here, we study it directly in games with unfair redistribution, i.e., with payoffs and endowments heterogeneity. Our experiment, easy to reproduce in the classroom, shows that contribution rates differ largely and proves that fairness plays a role in subjects' decisions to contribute.

II. Experimental design

Many authors observed different types in the subject population. For Ledyard, there are 50% Nash players, 40% Nash players if the incentives are high enough (but who also make mistakes) and 10% irrationals. The proportions of these types are not the main issue. What is important is that they are present. As it is well known in game theory or in experiments, a small proportion of altruists may change the behavior of a rational player. Thus, the detection of these behaviors is important. In this paper, we analyse several variations of a public goods experiment, in the same spirit as Hoaas and Madigan (1996). We test different games with more or less inequity to evaluate the influence of non-selfish considerations. In each game, the number of players is $n = 4$, but endowments z_i and payoffs u_i are different. This leads to the 11 cases (A to K) described in Figure 1.

Payoffs are expressed as the percentage of aT that a player receives (with a = 3/2). Normally, each player consumes the same public good and shares are identical. Thus, some games above do not correspond to a standard (pure) public good. But this is not crucial since in practice we often observe that individuals' consumptions of a public good are not similar. If we adopt player i's point of view, we can arrange the following games into five classes: fair, unfair for all players, unfair for player i, unfair for the opponents, and unfair for one of the opponents. Case A is "fair" since the proportions of players' payoffs to their endowments are all equal. Each player receives a share that depends on his means. Cases B, F, and J are "unfair for all players" since player i and all the other players are in the same situation, except one who has a proportion of payoff to endowment largely higher. Cases E and I are "unfair for player i" since he is the only one who has a proportion of payoff to endowment lower than those of the others. Cases C, G, and K are "unfair for the opponents" since player i has a proportion of payoff to endowment largely higher than those of the others. Finally, Cases D and H are "unfair for one of the opponents" since one of the opponents has a lower proportion of payoff to endowment. Figure 2 summarizes these classes.

Figure 1. Game structures

Game	Player i's endowment	Player i's payoff (%)	Others' endowments	Others' payoffs (%)
A	40	25	40 / 40 / 40	25 / 25 / 25
B	40	15	40 / 40 / 40	15 / 15 / 55
C	40	55	40 / 40 / 40	15 / 15 / 15
D	40	30	40 / 40 / 40	30 / 30 / 10
E	40	10	40 / 40 / 40	30 / 30 / 30
F	40	25	40 / 40 / 15	25 / 25 / 25
G	20	25	40 / 40 / 40	25 / 25 / 25
H	40	30	40 / 40 / 15	30 / 30 / 10
I	15	10	40 / 40 / 40	30 / 30 / 30
J	40	15	40 / 40 / 15	15/ 15 / 55
K	15	55	40 / 40 / 40	15 / 15 / 15

Figure 2. Game classification

Game types	**Game**
Fair	A
Unfair for all players	B/F/J
Unfair for player i	E/I
Unfair for the opponents	C/G/K
Unfair for one of the opponents	D/H

Among the four types of unfair games, we can note that the first two types (games B, F, J and E/I) are unfair for player i whereas the last two types (games C, G, K and D/H) are unfair for one or more other players. The purpose of this classroom experiment is to show that there are some differences in subjects' behavior due to their senses of fairness.

III. Experimental results

The experiment can be run during a course in microeconomics or game theory after the concept of Nash equilibrium has been discussed (see Brock, 1996, for the relevance of classroom experiments on public goods). We conducted our experiment at the University of Montpellier with 48 undergraduate subjects from several microeconomics classes. They were separated into 12 groups of 4 subjects. We used additional grade points as rewards. Subjects had to choose a contribution level after discovering the game structure, i.e.: their share of the public good, their opponents’ endowments and shares. Except for this information, instructions were similar to other experiments. Results clearly show that fairness is present because contribution rates differ largely:

Figure 3. Experimental results (player i’s contribution rates)

Game type	**Game**	**Rate**
Fair	A	60%
Unfair for all players (except one)	B/F/J	51%
Unfair for player I	E/I	47%
Unfair for the opponents	C/G/K	70%
Unfair for one of the opponents	D/H	67%

The rates indicated above are aggregated contribution rates from players i (see Appendix for detailed results). From this table, we can conclude that player i uses considerations of fairness to choose his contribution rate. When a game structure is unfair to himself as in games B/F/J or in game E/I, he reduces his contribution rate from 60% to 51% (games B/F/J) or 47% (games E/I). We observe that the decrease is higher when he is the only harmed player. Inversely, when a game structure is unfair for the opponents like in games C/G/K or in games D/H, player i increases his contribution rate from 60% to 70% (games C/G/K) or 67% (games D/H). We also observe that the increase is higher when he is the only one who takes advantage of the unfair structure. In other words, player i seems to compensate for the injustice by increasing his contribution and thus diminishing the free riding. This high rate also contradicts the considerations expressed by Stodder (1994) on the use of grade points, suspected to restrain cooperation.

IV. Conclusions

The purpose of our experiment was to show the relevance of players' sense of fairness in voluntary contributions to public goods. We observed that contributions were higher when the opponents (or one of them) was harmed by an unfair redistribution, and lower when the player we study was harmed by an unfair redistribution. These observations show that players' senses of fairness interfere with other preferences in the decision to contribute to a public good.

Finally, we can note that what we call fair or unfair is subjective from a political economy point of view. In effect, when an individual with a low endowment receives a higher share than his opponents, we qualify this as unfair, but many redistribution systems such as taxation precisely follow this for sympathy purposes. Thus, it is possible that in other contexts this situation would be perceived as fair by the subject.

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Appendix

Game	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Contribution	23.9	16.3	29.9	25.1	13.5	20.2	9.3	28.3	9.2	23.7	13.5
Rate	59.7	40.7	74.7	62.7	33.7	50.5	46.5	70.7	61.3	59.2	90.0

A Production Possibilities Frontier Experiment: Links and Smiles

David A. Anderson and James Chasey***

In the teaching of college and advanced placement economics, some of the characteristics of the production possibility frontier (PPF) are as difficult to convey as they are important to understand. John Neral and Margaret Ray (1995) suggest a useful and instructive classroom experiment in which two products, "widgets" and "whajamas," are produced to study tradeoffs between outputs. Tearing a piece of paper in half, folding it twice, and stapling it creates a widget; folding the paper three times makes a whajama. We have designed the links and smiles experiment to incorporate one of the most challenging concepts to grasp in relation to the PPF—the specialization of inputs. Of course, it is this crucial factor that results in the increasing opportunity cost of production and the concave shape of the production frontier.

This experiment has been run numerous times by at least five instructors. All report that their students benefited from the opportunity to work with and transform specialized resources from one use to another. Having acted as producers and derived PPFs themselves, students come away with a better understanding of resource specialization, increasing opportunity costs, and the tradeoffs incumbent in our every decision. In subsequent classes, instructors were able to refer back to this experiment as a reminder and reinforcement of the inherent concepts.

Time Required: Approximately 30 minutes

Materials *for each student*:

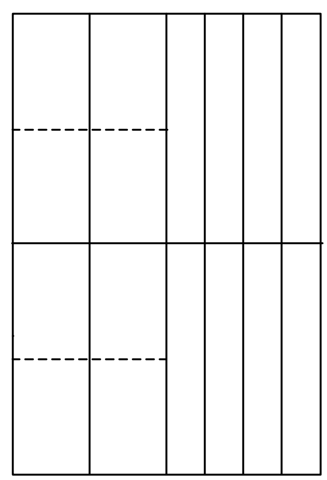
- 2 sheets of 8½x 11 paper
- 1 roll tape
- 1 pair scissors
- 1 pencil or pen

Objective:

This game allows students to derive and get a feel for production possibilities frontiers. After experimenting with different allocations of resources, students can discuss the reasons for increasing opportunity costs based on personal insight.

Setup:

There are two paper inputs used in this experiment: 5½" x 1-1/16" strips, and 2¾" x 1-1/8" rectangles. To obtain enough of each paper input for the whole experiment, have each student stack two sheets of paper, and ask them to: 1) fold the two most-distant ends together; 2) fold the new most-distant ends together; 3) undo the last fold and fold each of the most-distant ends in so that they touch the center line; 4) without doing any unfolding, fold *one* side in once more so that it touches the center line. Now if they unfold their papers, cut along the creases, and cut the four wider strips in half as indicated by the dotted lines, they will have 16 strips and 16 rectangles.



Outputs defined:

Student producers will be producing links and smiles. A *link* is a 5½" x 1-1/16" strip of paper wrapped into a circle and taped in place. Subsequent links are put through the previous link and taped to interconnect the links into a "paper chain."

A *smile* is produced by using scissors to round the four edges of a 2¾" x 1-1/8" rectangle and drawing two eyes and a smile on one side of the circle.

Note to students that although strips are best for making links, and rectangles are best for making smiles, creative cutting and taping will permit strips to be made into regulation smiles and rectangles to be made into regulation links. (That is, if they cut the strips/rectangles in half and tape the halves together appropriately, they can make a rectangle out of a strip and vice-versa.)

Conducting the experiment:

1. For each round, students begin with 4 strips, 4 rectangles, a pen, a roll of tape, and a pair of scissors.

2. Explain that resources may not be carried over from one period to the next, and that only one layer of paper may be cut at a time.

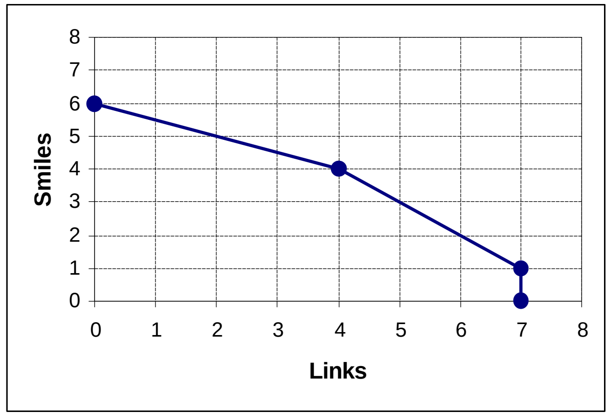
3. After explaining the objective of the round (see below), give the students 70 seconds of production time.

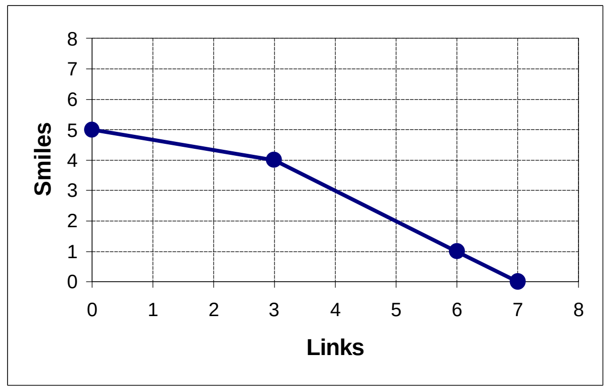
   Round 1: Make four smiles and as many links as you can.
   Round 2: Make only links.
   Round 3: Make only smiles.
   Round 4: Make one smile and as many links as you can.

4. Ask the students to record the number of links and smiles they produce in each round.

Discussion:

Have the students draw their PPFs on the board. The following are graphs from a typical links and smiles experiment:





In class, or for homework, ask the students:

"What was the opportunity cost of the first smile?"

(Zero links in the top graph, one link in the bottom graph.)

"What was the opportunity cost of the last 1 or 2 smiles?"

(Four links for two smiles in the top graph, three links for one smile in the bottom graph.)

"Why did the opportunity cost increase?"

(Due to the specialization of resources. To make the first few smiles, we use resources that are better for making smiles than making links, so we give up a small number of links for a relatively large number of smiles. As we make more smiles, we must use resources that are more specialized for making links, so we lose a lot of links for relatively few smiles.)

"How does this relate to real-world production possibilities?"

(Resources are specialized in the real world as well. For example, the inputs to butter production are less useful for making guns. If we wanted to produce only guns, after using the resources best suited for gun production, we would have to melt down the steel vats used to make butter and mold them into guns. This is analogous to altering link-specialized strips for use (however inefficiently) in smile production. Similar specialization of resources, and the increasing opportunity costs of production that results, exists for many of the goods we consider producing.)

"What would the PPF look like if our two products were smiles and frowns (frowns are just like smiles except for the shape of the mouth)?"

(It would be a straight line with a slope of –1 because every smile that we made would result in one fewer frown.)

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A Keynesian Beauty Contest in the Classroom

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Most models of economic behavior are based on the assumption of rationality of economic agents and common knowledge of rationality. This means that an agent selects a strategy that maximizes his utility believing that all others do the same (are equally rational) and that all agents believe that all others believe that all agents are rational etc.

The p-beauty contest game is an appropriate game to test the assumption of this kind of reasoning. In this game a player has to guess what the average choice is going to be and the player will win if his choice is closest to some fraction of the average choice. Think of a seller in the stock market. He wants to sell his shares just before the average person is selling, thus when the price of the share is at its peak. Therefore, he does not want to sell it too early. As a consequence if everybody thinks like him, the selling time is unraveling. Unraveling can be seen in many real world markets, such as entry-level medical labor markets or clinical psychology internships as documented in Roth and Xing (1994). The name of the game is due to Keynes (1936, 156) who compared a clever investor to a participant in a newspaper beauty contest where the aim was to guess the average preferred face among 100 photographs.

The experiment can be introduced in many different courses and at all levels of teaching. For example in game theory in order to discuss the issue of iterated elimination of (weakly) dominated strategies and common knowledge of rationality; in macroeconomics to discuss rational expectations; in microeconomics to discuss strategic interaction between players.

I. The rules of the basic beauty contest game:

The rules of the game are straightforward. Elements of the rules (indicated by bold/italic) can be varied in many ways (below I give some suggestions about different treatments):

Each person of ***N-players*** is asked to choose a (***real*** or ***integer***) number from the ***interval 0 to 100***. The winner is the person whose choice is closest to ***p*** times the ***mean*** of the choices of all players (were p is for example ***2/3***). The winner gets a ***fixed*** prize of ***$20***. In case of a tie the prize ***is split*** amongst those who tie.

The same game may be repeated ***several periods.*** Subjects ***are informed*** of the ***mean, 2/3 mean*** and ***all choices*** after each period.

The students should write down a brief comment how they came to their choice.

Time to think: about ***5 minutes*** or as a ***take home task.***

II. The game theoretic solution and the contrast to a bounded rationality model using the basic game

In equilibrium all players have to choose zero. Figure 1a. describes the process of iterated elimination of weakly dominated strategies for p=2/3. A rational player does not simply choose a random number or his favorite number, nor does he choose a number above 100p, since it is dominated by 100p. Moreover, if he believes that the others are rational as well, he will not pick a number above $100p^2$, and if he believes that the others are rational and that they also believe that all are rational, he will not pick a number above $100p^3$ and so on, until all numbers but zero are eliminated. If the number of players is 2, 0 is a dominant strategy. There are no other equilibria in the (in)finitely repeated game. If p>1 then the upper bound of the interval is also an equilibrium. For p = 1 any number chosen by all players can be an equilibrium.

In contrast to the iterated elimination of dominated strategies, figure 1b. shows another process, the process of iterated best reply, which better explains actual behavior. The elimination process does not start at 100 but instead at 50, because a player will, for insufficient reasoning, think that any number is equally likely; therefore the mean should be 50. Thus best reply is 2/3*50=33.33. If everybody thinks that way best reply should be 22.22 and so on.

Equilibrium ←———— ITERATION ←————

... ...	E(4)	E(3)	E(2)	E(1)	E(0)

0 13.1 19.75 29.63 44.44 66.66 100

Figure 1a.) Infinite process of iterated elimination of dominated strategies for p=2/3. E(0) is the area of dominated choices, E(1) is the area of one iteration of elimination and so on. Adapted with permission from Ho et al. (1998).

Equilibrium ←———— ITERATION

	E(3)	E(2)	E(1)	

0 14.9 22.22 33.33 50 100

Figure 1 b.) Infinite process of iterated elimination of best replies, starting at 50.

III. Why is a study of human behavior with this game interesting?

1.) There is a clear distinction between bounded rationality and the game theoretic solution in the basic game. Game theory predicts a unique game theoretic solution that all players choose 0. Most actual players do not behave according to this solution. There are two explanations: Either because a subject chooses a strategy at random or just reasons one level using the hints of the mean and the parameter 2/3. Or he thinks that the others are not as clever as he is and therefore he does not reason very far himself.

2.) This kind of boundedness does not arise as an outcome of motivational factors such as fairness or cooperation, which typically explain the deviations from theory in other games. We are facing here a pure strategic game (constant-sum game) where there is no room for cooperation. The behavior can be interpreted as "pure bounded rationality".

3.) The behavior can be categorized into different levels of reasoning via iterated best reply or iterated elimination of dominated strategies.

Each single aspect can be also found in other games but the combination of all three are not easily met at once in other games. Furthermore, it is very easy to change the rules of the game in such a way that the iteration process leads with a few or even infinitely many eliminations to equilibrium.

IV. Results of actual behavior

a.) Results in the first period:

Figures 2a-c. show the relative frequencies of choices in the first period of a.) lab-experiments with Bonn undergrad students; b.) experiments with game theorists run in several conferences; and c.) experiments run in different newspapers. Note that in all treatments there are high picks near or at 22 and 33. Game theorists and newspaper readers exhibit the largest modal frequency of behavior at or near the equilibrium zero. Dominated choices are rarely chosen. The following comment by a high school class (submitted to one of the newspaper studies, the Spektrum der Wissenschaft) summarizes the most important thought processes:

> I would like to submit the proposal of a class grade 8e of the Felix-Klein-Gymnasium Goettingen for your game: 0.0228623. How did this value come up? Johanna … asked in the math-class whether we should not participate in this contest. The idea was accepted with great enthusiasm and lots of suggestions were made immediately. About half of the class wanted to submit their favorite numbers. To send one number for all, maybe one could take the average of all these numbers.
>
> A first concern came from Ulfert, who stated that numbers greater than 66 2/3 had no chance to win. Sonja suggested to take 2/3 of the average. At that point it got too complicated to some students and the finding of the decision was postponed. In the next class Helena proposed to multiply 33 1/3 with 2/3 and again with 2/3. However, Ulfer disagreed, because starting like that one could multiply it again with 2/3. Others agreed with him that this process then could be continued. They tried and realized that the numbers became smaller and smaller. A lot of students gave up at that point, thinking that this way a solution could not be found. Others believed to have found the path of the solution: one just has to submit a very small number.
>
> However, one could not agree how many of the people who participated realized this process. Johanna supposed that the people who read this newspaper are quite sophisticated. At the end of the class 7 to 8 students heatedly continued to discuss this problem. The next day the math teacher received the following message: We think it best to submit number 0.0228623.

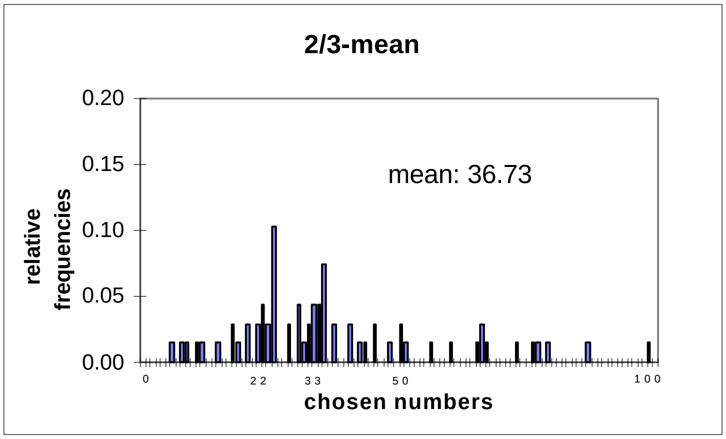

Figure2a) lab-data. With permission from Nagel (1995)

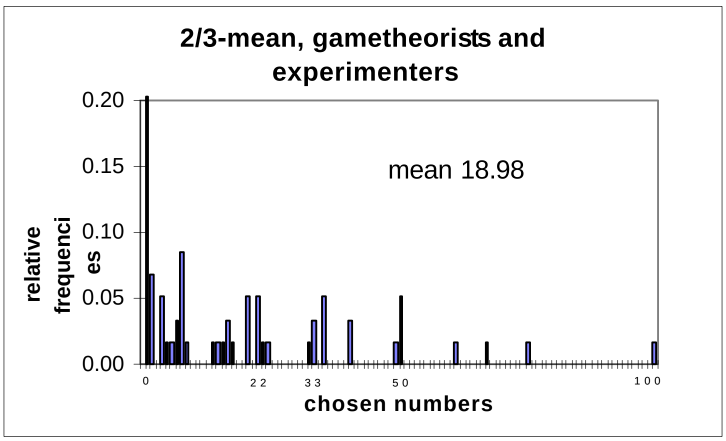

Figure 2b) game theorist data

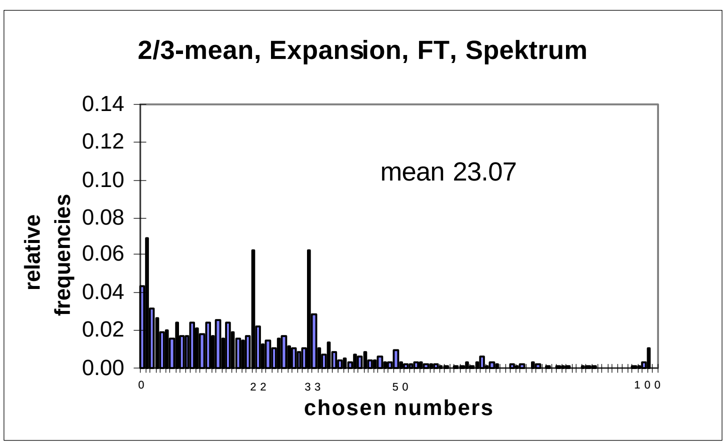

Figure 2c) newspaper readers data

b.) Results over time:

Figure 3 shows the behavior over time in some selected treatments. In general behavior converges to equilibrium. The speed of convergence depends on the parameter used. Typically the reasoning process from period to period is anchored to the mean of the previous period. Level 1-reasoning is then 2/3 times the mean of the previous period, level 2-reasoning is 4/9 times the mean of previous period and so on. The average level of reasoning typically applied by subjects does not increase over time.

V. Further readings and treatment suggestions

Nagel (1995) discusses the basic game with parameters p = 2/3, ½ and 4/3 played for 4 periods with about 15 students. Ho et al (1998) discuss the game with group size 3 and 7, and intervals from [0,100] or [100,200] and several parameters p. Thaler (1998) discusses his newspaper results in connection with financial economics. Nagel et al (1999) compare the behavior in experiments run in three newspapers, run with game theorists and lab experiments. Nagel (1998) presents a survey of beauty contest experiments and analyses the case where the prize to the winner is his choice paid in dollars. Rubinstein (1999) lets his students play the basic game among other games on his webpage.

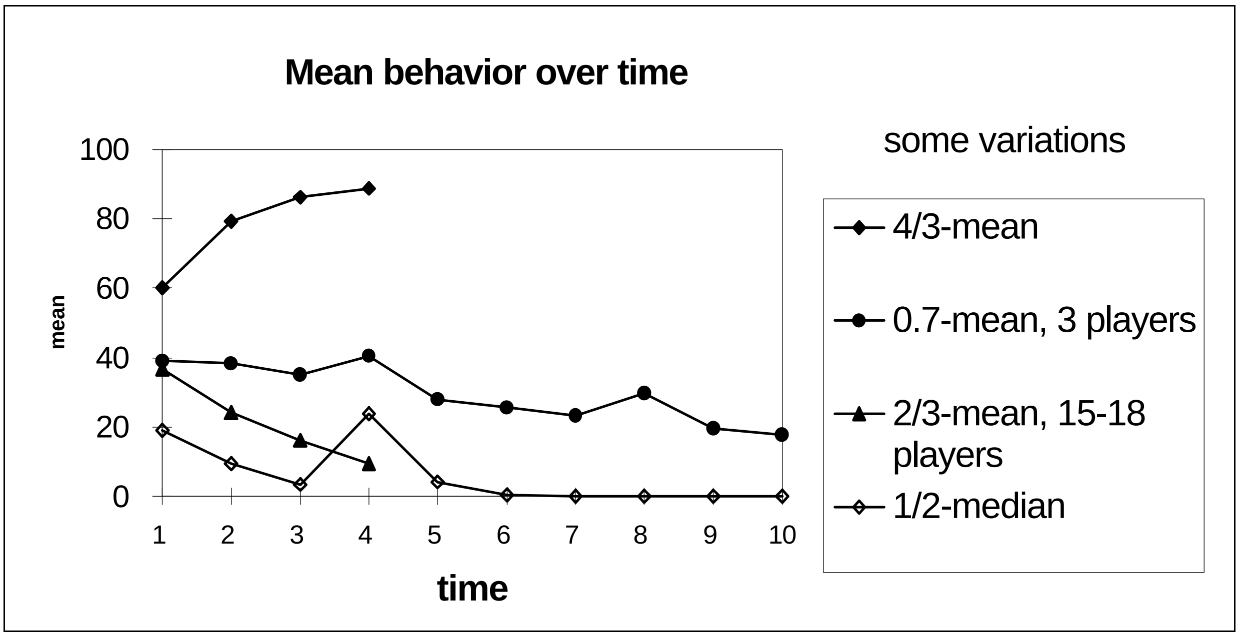

Figure 3: Mean behavior over time for different variations.

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