UNIVERSITÄT LEIPZIG
INSTITUT FÜR SOZIOLOGIE

FNSNF
SCHWEIZERISCHER NATIONALFONDS
ZUR FÖRDERUNG DER WISSENSCHAFTLICHEN FORSCHUNG

Can Roger do, what Roger can? Optimal serving in tennis

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Seminar at Venice International University, San Servolo, December, 3-7, 2007

Rational decision in zero-sum games

- In standard theory rational deciding consists of two elements:
  1. Completely selfish preferences, and
  2. the (cognitive) ability to decide in order to maximise the corresponding utility.
- In zero- (or constant) sum games the interests of the actors are by definition contrary to each other. So, the first condition is always fulfilled.
- The problem of rational decision therefore is constrained to find and follow the utility maximising strategy, say the Minimax solution.

A simple example: Matching pennies

The pursuer tries to catch the evader. That one tries to hide in- or outside. If they meet the pursuer wins. If not, the evader does.

		PURSUER			
		in		*out*	
EVADER	*in*	-1	1	1	-1
	out	1	-1	-1	1

pursuer: $\{in/in\} > \{out/in\}$ $\{in/out\} < \{out/out\}$

evader: $\{in/in\} < \{in/out\}$ $\{out/in\} > \{out/out\}$

Minimax solution: Both chose *in* or *out* with a probability of 0.5.

Where does the rationality com from in such a case?

Two concepts:

1. Rationality is an *individual* property, acquired by reinforced learning in a certain interaction. Rational decision then might happen rather subconsciously (Raab und Johnson 2006).
   - The more often an actor has run through an interaction, the closer to optimum his decisions should be (H1).
   - The simpler an interaction is (e.g. less vs more options), the closer to optimum decisions should be (H2).
2. Rationality is an *emergent*, ,,ecological" property of the interaction structure (Becker 1962, Coleman 1986/1990, Smith 2003).
   - So, in highly competitive interactions are (e.g. zero-sum games) decisions should be close to optimum (H3).

I: Minimax play of *professional* tennis players (H1/H3)

- Hsu et al. (2007) find optimal play for a selection of male, female, and junior players.
- Walker/Wooders (2001) find optimal play for a selection of male players.
- Klaasen/Magnus (2001) find for all Wimbledon games from 1992-1995 that stronger players are closer to optimum, than weaker ones, though none of them completely reaches it.

I: Minimax play of *professional* football players (H1/H3)

- Chiappori et al. (2002) and Palacios-Huerta (2003) find optimal mixture between left and right in penalty kicks for a selection of penalty kicks from major European leagues.
- Berger/Hammer (2007) find optimal mixture between left and right in all penalty kicks for the goalkeepers and close to optimum play by the strikers in the Bundesliga from 1993 to 2004.
- Moschini (2004) finds optimal mixture between left and right for shooting from wing position to the goal in the Serie A.
- Berger (mimeo) finds mixed evidence for the strategies (left, center, right) of goalkeepers in penalty kicks. While goalies in the Bundesliga act optimal, goalies in other European leagues do so only in tendency.

IV: Minimax play in the laboratory by *untrained* actors (see Berger/Hammer 2007 for literature)

- Generally humans do not easy randomize decisions in laboratory experiments and tend to form patterns.
- Subjects tend to fail the more complex the game is (e.g. in 4×4 games rather than in 2×2 games)(H2).
- Generally untrained actors tend to fail in mixing their actions,
- though they get better, after having repeatedly played the game (H1).

II: Minimax play in the laboratory by *trained* actors

- Professional and amateur football players act optimal in the laboratory, in a game where lay people fail (Palacios-Huerta / Volji 2006) (H1).
- But, Levitt et al. (2007) find no evidence that professional
  - poker,
  - bridge,
  - football players

  did play any better than lay people in the same laboratory games.
- This was the case though mixing actions
  - is crucial for skillfully playing poker,
  - is of certain importance for football players (not only in penalty kicks),
  - but plays no role in bridge (H1/H3).

Summary of the the know evidence

+ : Minimax play confirmed
– : Minimax play not confirmed

	field	*laboratory*
professionals	**I**: + +	**II**: + –
amateurs	**III**: ? ?	**IV**: – –

Amateurs acting in the field: Serving in tennis

- The serving player in tennis brings the ball into play, by hitting it from behind of one side of his field across to the the serving field of the receiving player.
- The receiving player expects the ball standing wherever he wants on his side of the net, and tries to hit back the ball wherever he wants to in the field of the server.
- As soon as one player fails to hit back the ball into his opponent's field according to the rules, the other one makes the point.

Decision problem while serving in tennis

- Following Walker/Wooders (2001) and Hsu et al. (2007) the server's decision is modeled with two options:
  1. Serving to the *left* end of the serving field.
  2. Serving to the *right* end of the serving field.
- Because there is no dominant strategy to serve exclusively in one of the two corners (the receiver would wait there and hit back the ball with ease), the server has to mix these two options.
- He will do that, so to *make the receiver indifferent* between both options (and vice versa).
- So, in equilibrium the win rates of making the point must be equal for both options available (H4).

Serving decisions from a game theoretic view

- The receiver tries to guess the serving direction.
- The server tries to avoid the direction expected.
- If the receiver guesses right, his chance of winning the point increases (and the server's decreases), and vice versa.

The expected win rates of the server are noted. (The win rates of the receiver are $1 - \pi$)

		RECEIVER: *left*	RECEIVER: *right*
SERVER	*left*	π_{LL}	π_{LR}
	right	π_{RL}	π_{RR}

Data sets (data collection: Thomas Lehnert)

Professionals: Swiss Indoors 2007, won by Roger Federer.

- 7 matches including one semifinal and the final.
- 787 serves (431 to the right, 356 to the left).

Amateurs:

1. Verbandsliga I Berlin/Brandenburg Gruppe B, winter 2008.
   - The winner is ranked about no. 500 in the DTB.
   - 3 matches with 318 serves (192 to the right, 126 to the left)
2. USTA Championships Southern Division - NC, autumn 2007.
   - One player is a tennis coach.
   - 4 matches with 485 serves (252 to the left, 233 to the right).

Amateur players

	serves won		serves lost		win rates		χ^2-test	set score		
PLAYERS	L	R	L	R	L	R	p-value	1.	2.	3.
Teurer	15	23	13	23	53.6	50.0	0.766	6	2	7
Leickhoff	20	29	18	29	50.0	52.6	0.801	2	6	6
Kunkel	16	7	7	1	69.6	87.5	0.318	6	6	-
Reckert	2	5	6	6	25.0	45.5	0.361	0	1	-
Szabados	8	19	12	19	40.0	50.0	0.468	4	2	-
Teurer	9	17	1	14	90.0	58.8	0.045	6	6	-
Sandman	7	20	5	12	58.3	62.5	0.800	6	6	-
Huggins	14	13	24	13	36.8	50.0	0.295	4	3	-
Sutton	24	10	18	8	57.1	55.6	0.909	6	6	-
Rincon	13	17	10	22	56.5	43.6	0.325	4	4	-
Oxendine	13	22	11	6	54.2	78.6	0.061	6	6	-
Ecos-Ossio	16	12	13	10	55.2	54.2	0.964	3	1	-
Oxendine	21	28	17	20	55.3	58.3	0.775	3	6	-
May	18	26	9	13	66.7	66.7	1.000	6	7	-
overall	196	248	163	196	54.6	55.9	0.721	-	-	-

Professional players

PLAYERS	serves won		serves lost		win rates		χ^2-test	set score		
(rank no.)	L	R	L	R	L	R	p-value	1.	2.	3.
Blake (14)	19	17	2	3	90.5	85.0	0.592	6	6	-
Hernandez (59)	13	16	4	16	76.5	50.0	0.073	3	4	-
Wawrinka (36)	20	27	7	7	74.1	79.4	0.622	7	6	-
Nalbandian (9)	19	19	9	11	67.7	63.3	0.717	6	2	-
Mathieu (25)	17	15	7	4	70.8	79.0	0.545	6	6	-
Dancevic (69)	12	17	18	12	40.0	58.6	0.153	3	1	-
Federer (1)	21	16	5	9	80.8	64.0	0.180	6	6	-
Del Potro (44)	4	13	6	13	40.0	50.0	0.590	1	4	-
Mathieu (25)	24	17	13	13	64.9	56.7	0.493	2	6	-
Baghdatis (16)	26	22	9	12	74.3	64.7	0.387	6	7	-
Karlovic (22)	28	30	9	8	75.7	79.0	0.735	6	6	-
Federer (1)	20	40	6	10	76.9	80.0	0.755	7	7	-
Federer (1)	16	23	4	11	80.0	67.7	0.328	6	6	-
Nieminen (27)	11	21	5	9	68.8	70.0	0.930	3	4	-
overall	250	293	106	138	70.2	68.0	0.498	-	-	-

Comparison of amateurs and professional players

- No apparent difference between amateur and professional players (H1):
  - Only a few players fail in making their opponent indifferent in their choice of the side (H4).
  - Overall, win rates on both sides are close to each other.
- This is the case, though the serving win rates of the amateurs are clearly lower than those of the professionals.
- Possibly, in competitive matches, win rate mixing is closer to optimal than in lopsided matches (H3).

Summary: Minimax play of amateurs

- Amateurs seem to be able to play Minimax in the field under real competitive conditions (H4).
- So, rationality, here seems to be - also - a property of the interaction, and not solely of the actors.
- Though, admittedly here
  - the amateur players already are pretty experienced. (This is necessary to ensure that the observed serving direction is also the intended one.)
  - the decision between two option is not too complex.

Serving as a test for Minimax decisions: Remaining problems

- There is only an indirect connection between successful serving and making the point.
- Any selection bias for the observed matches should be avoided.
- Modeling the quality of the players might lead to other equilibrium points, (too).

Beyond serving: Examples for interactions with mixed equilibria solutions

The interaction structure can be found whenever the interest of the players are completely opposite to each other, e.g.:

- In a lot of sports and games.
- In interaction between a deviant and a controller (see Tsebelis 1990, Rauhut 2006)
- In interaction between a pursuer and an evader (,,Hide and Seek", ,,Sherlock Holmes" and ,,Prof. Moriarity" in the ,,Final Adventure").
- In warfare (,,Battle of the Bismarck Sea").