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Why were you initially drawn to game theory?

I could answer this question by simply saying that I studied at the Hebrew University of Jerusalem which was home to many of the giants of game theory and related fields: Yisrael Aumann, Arie Dvoretzky, Bezalel Peleg, Menachem Yaari, Michael Rabin and Amos Tversky. So what else would you expect? But that would only be a partial answer.

I could say that it is the ingenious name given to the field – game theory – which attracted me. I doubt if I would have chosen a field called "Theory of rationality and decision making in interactive economic situations." But in fact my first encounter with game theory was a disappointment. In my second undergraduate year (1972–3), I tried out a course given by the Mathematics Department entitled *Introduction to Game Theory*. I remember that the lecture hall was full and the lecturer very enthusiastic. He started the course with some abstract theorems on convexity. I left before the end of the first class.

I could also say that I chose game theory because I wanted to improve my strategic skills for the crusades on which I was hoping to embark in the future or to improve my negotiating abilities in the open-air markets of Jerusalem. But that wouldn't be right either. I have never thought of game theory as being useful in a practical sense. In fact, I was quite shocked in 1987 when I discovered for the first time that some of my fellow economic theorists believed that a model should be confirmed in the laboratory or using real empirical data.

The seeds of my interest in game theory were planted during my undergraduate studies in mathematics at the Hebrew University. While I admired the intellectual beauty of the material, I had a

vague notion that, despite its abstractness, mathematics had some connection to real life. So I tried to superimpose the mathematical models onto the subject that occupied my thoughts both then and now: the realm of human interaction. Somewhere between mathematics and the study of human interaction, game theory awaited me.

What example(s) from your work (or the work of others) illustrates the use of game theory for foundational studies and/or applications?

Implicit in this question is the idea that game theory can and probably should be evaluated according to its usefulness. The phrase "the use of game theory" which appears in the question sounds analogous to "the use of physics in the design of rockets" or "the use of biology in the identification of genetic diseases." In my opinion, it isn't analogous.

The discussion of the usefulness of game theory (or for that matter economics in general) is charged with emotion and subject to misunderstandings. The everyday terminology of game theory attracts people's attention but for the wrong reason. Human beings are eager to find professional solutions to problems they tackle. They look for techniques and ideas to improve their strategic skills as if they were weight training to build up their athletic skills. In my thirty years in the profession I have not encountered a single case in which game theory has provided a solution to a real problem and have not found any evidence that it has the ability to improve strategic thinking.

An article I read in the Israeli newspaper *Haaretz* while writing this essay demonstrates the public's confusion about game theory. A former senior politician was writing about the current tension between Iran and Israel. He claims that game theory is already able to explain the interactions between two rational players. He also states that according to game theory an irrational player has an advantage over a rational one. (In my opinion, this is a myth promoted by hardliners who want to persuade rational people to act "tough.") But then he claims that at the moment no one knows how to analyze a game between two irrational players. He goes on to assume that the President of Iran is irrational and that the Israeli government has recently adopted an irrational strategy by appointing one of the most controversial politicians as the Minister in charge of dealing with strategic threats. This leads him to call

on game theorists, and Robert Aumann in particular, to "save us."

This person obviously takes game theorists seriously when they claim that game theory is useful. This claim is often made and not only in NSF proposals. Almost any survey of game theory starts with a sentence like "Game theory is useful in a wide spectrum of fields—from Botany, Zoology and Medicine through Economics, Management, Computer Science and Politics to History and Biblical Studies." However, the fact that the "prisoners' dilemma" is mentioned in a text does not make it an application of game theory. And the fact that game theorists are involved in a discussion does not make it an application of game theory.

Let us recall that game theorists and economists are in the end only human. Paradoxically, we assume that all agents in the world are selfish and manipulative and act to advance their own interests, but somehow we are not used to thinking of ourselves in this way when we assess the usefulness of our own models.

I believe that one of society's goals should be the pursuit of knowledge and scholarship for their own sake. For me, game theory is an investigation of the ways in which human beings think in interactive situations. Even if game theory is of no practical use, it still has value as part of our continuing investigation of the mind.

What is the proper role of game theory in relation to other disciplines?

How would one answer the following question: "What is the proper role of logic in relation to other disciplines?" I would argue that if the word "logic" were replaced with "game theory" the answer to this question would be the same.

There are many similarities between logic and game theory. Whereas logic is the study of truth and inference, game theory is the study of strategic considerations. Logic is motivated by the way in which we use the notions of truth and inferences in daily life while game theory is motivated by the strategic considerations we use in daily life. I doubt whether there is a type of logic which is "right"; in the same way, there is no one type of game theory that is "right". The standard rules of logic have a unique status; similarly, rationality has a unique status in economics. Both logic and game theory are analyzed using formal models. Logic does not induce people to think logically just as game theory does not

induce them to think strategically. So what is the role of logic or of game theory in relation to other disciplines? The answer is simply that both provide a limited set of ideas and tools for use in those other disciplines.

Let me demonstrate the proper role of game theory in relation to other fields using a project I am involved in together with Kobi Glazer (see for example, Glazer and Rubinstein (2006)). The project involves research into pragmatics, a branch of linguistics that explores the rules that determine how people interpret an utterance made in a conversation beyond its literal content. We are interested in persuasion situations where an informed party wishes to persuade an undecided and uninformed party to adopt his position. The difference between this situation and a regular conversation lies in the interests of the two parties. In a conversation there is an underlying assumption that the two parties have common interests while the parties involved in a persuasion situation have at least a partial conflict of interest. The speaker wants to persuade the listener to believe what he says while the listener wishes to be persuaded only under certain circumstances.

We noticed that a persuasion situation is subject to different rules of pragmatics than a conversation. For example, assume that you are discussing the chances of each of two candidates – A and B – in upcoming elections and that the electorate consists of nine voters. Assume that the speaker knows the positions of all the voters but due to time constraints can only present the views of three of the nine (who are enumerated as c_1 to c_9). The speaker claims that candidate A will win and presents evidence that c_1, c_4 and c_8 support A. If it is a friendly conversation and the speaker's interests are similar to yours, then you are likely to think that he has selected three people who represent the view of the majority. Thus, you are likely to conclude that A will win the election. If, on the other hand, it is clear that the other person is trying to persuade you that A will win, regardless of whether this is true or not, you will doubt his claim since you suspect that he has intentionally selected three supporters of A and that c_2, c_3, c_5, c_6 and c_7 weren't mentioned, even though they appear before c_8 in a list, because they support B.

In this project, we attempt to provide an explanation for this sort of pragmatic phenomenon using an "economic/game theoretic approach." We assume that pragmatic rules of persuasion are determined by an imaginary designer prior to the conversation. The rules of pragmatics determine the "game" played between the

speaker and the listener in such a situation. We assume that the designer wishes to maximize the probability that the listener will make the "right" decision on the basis of the information provided to him by the self-interested speaker subject to the constraints on the amount of information that can be conveyed. In such a model one can show that according to optimal persuasion rules the presentation of evidence regarding certain combinations of voters is persuasive while others, which include the same number of voters, are not.

Our investigation applies economic/game theoretic principles to pragmatics. I don't know whether people in other fields have thought along similar lines, but I am quite certain that stating these ideas clearly requires the sort of formal and conceptual tools that have been developed and used in economics and game theory. But I am also aware of the fact that the assessment of the results of such an approach requires the expertise possessed by philosophers and linguists rather than game theorists. Game theory's tools can produce possible explanations but cannot evaluate them.

What do you consider the most neglected topics and/or contributions in late 20th century game theory?

I do not feel comfortable with the term "neglected topic" which seems to imply that there are areas which game theory should be investigating but isn't. Thus, I will simply list five topics in game theory that represent significant contributions during the late 20^{th} century:

1. **The Interpretation of Game Theory**: My impression is that more and more game theorists are struggling with the interpretation of game theory. Is it a theory as that term is understood in the sciences or is it a collection of fables (see Rubinstein (2006))? This is not a question that can be settled one way or another but the discussion and clear statement of the issues are crucial.

2. **Behavioral Game Theory**: In both economics and game theory, behavior is defined as rational if it can be described as an attempt to advance a well-defined goal. In applications of game theory and economics, rationality is usually defined more narrowly so that the goal is physical and "rational," such as the probability of survival or the level of

consumption. The application of game theory which also relates to goals has become increasingly common during the last two decades under the rubric of Behavioral Economics. Although this shift has not affected abstract game theory, which is indifferent to the content of the preferences, it is part of a major trend in economics in general and has had a major impact on the way in which game theory is applied.

3. **Models of Bounded Rationality**: Little work has been done to develop game theoretic models in which rationality is replaced with alternative choice procedures. The development of theories of interaction between agents who don't behave according to the rational man paradigm requires a major change in the solution concepts and not just in the payoff functions (which is all that is needed in order to include psychological elements within the model). One example of such a model is Osborne and Rubinstein (1998). In that model, we assume that each player constructs beliefs about the consequences of his actions on the basis of past experience. Thus, he attaches to each action the consequence which was observed when the action was taken on previous occasions. An S-1 equilibrium consists of a distribution of actions among each of the players such that the probability assigned to a particular action being played by a particular player is the probability that the player will consider that action to be optimal given his random sampling of past experience. This solution concept has some desirable properties. For example, the repetition of an action can affect the solution and a dominated action can still be played with positive probability.

4. **Experimental Game Theory**: We have seen significant development in this area though I am not happy with the direction it has taken. Researchers in this field insist on experiments being carried out in laboratories and using monetary rewards. I feel this to be unnecessary and simply intended to create barriers of entry. In addition, the field is characterized by small and unrepresentative samples and hastily-drawn conclusions and there is no widespread practice of replicating experiments.

5. **Neuro Game Theory**: This is a new trend in game theory in which researchers attempt to explain behavior by observing brain activity. Unfortunately, this line of research has

gotten ahead of itself. At this stage, the conclusions drawn are wildly speculative. But, of course, I cannot rule out the possibility that significant progress in the understanding of brain functioning in general will some day provide interesting ideas for Game Theory as well.

What are the most important open problems in game theory and what are the prospects for progress?

The term "open problems" may be appropriate for a field like mathematics in which the problems are usually clear-cut and simply waiting for a genius to solve them but it isn't relevant for game theory whose main goal is to formulate and clearly state problems. In any case, I would like to refrain from simply listing ideas for future research in game theory and that is for two reasons: (i) If the idea is original then I would use it myself, ... and (ii) If my suggestions lead others to develop interesting models, then they might feel obliged to give me credit that in fact I wouldn't deserve. A worthy achievement in game theory does not involve declaring some vague goal or inventing some catchphrase but rather building a simple but rich model that enables one to derive interesting results.

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