

## **Lloyd Stowell Shapley: In Memoriam**

An era is ending and almost all of us who were there at the start of the growth of the theory of games have died. Lloyd's mind, unfortunately left us several years ago when he was felled with dementia. Being the analyst that he was he said to me a year or so before he accepted (with much misgiving) the Bank of Sweden's prize in honor of Alfred Nobel that he was worried that there were signs that he might be following his father Harlow Shapley, a famous astronomer, who was felled by dementia in his 80's. Lloyd said that his doctor had commented to him that he was too old to contract Alzheimer's disease but that he had premonitions about dementia.

Lloyd was born on June 2, 1923 in Cambridge Massachusetts, the fourth child and third son of Harlow and Martha Betz Shapley who gave up the potential of an independent career to help her husband at the observatory and to bring up five children. Prior to World War II Lloyd was an undergraduate at Harvard, where according to him he was somewhat bored with academe and made a bet that if one could be good enough at judging the professor and the subject that you could get the grade you felt like getting. Thus in order to obtain a D in an exam one might have to sleep through much of it. He noted that the Harvard examiners were not amused.

World War II had Lloyd swept in as an enlisted man sent to Western China where his task was to decipher Russian codes. He succeeded in breaking them. It is comforting to know that on occasion a bureaucracy manages to fit a square peg into a square hole.

After the war Lloyd finished his Harvard A.B. and in 1948 joined the newly formed Rand Corporation. While attending a von Neumann lecture he suggested modifications to the analysis presented. Von Neumann was sufficiently impressed that he recommended that Lloyd be given a leave from Rand and support to go to The Mathematics Department at Princeton to get his PhD. He went to Princeton in 1949 and in 1953 obtained his PhD writing on Additive and Nonadditive Set Functions with his thesis advisor being Albert W. Tucker.

At Princeton he was a Fine Instructor from 1952-54. He was suggested as a potential assistant to Albert Einstein, but he commented that he saw no point in working for an old physicist who had made no basic contributions for many years when he was in a period of high productivity himself. He felt that that type of position would be better occupied by a reflected fame seeker. Another person took the job.

My first introduction to Lloyd was after the lottery that at that time involved suite and room selection at the Graduate College at Princeton in September 1949. The random selection had a suite assigned to Shapley, Nash and myself. There were only two bed rooms. Lloyd and I shared one and Nash had the other. It took us very little time to comprehend that John who was both younger and immature gave every indication of being brilliant and being extremely disturbed.

Lloyd regarded himself as essentially a mathematician and his love was pure mathematics, yet in spite of himself he became hooked into game theory and made original and profound contributions to every aspect of it. He emerged as possibly the most profound game theorist, beyond von Neumann until now.

Shapley did not generate models in political economy per se, but once he was presented with even a half-baked model he quickly showed a deep understanding of the problem at hand and tightened both the mathematics of the problem representation and its relevance in application. No other mathematician working in game theory, to my mind has shown anywhere near his practical insights and practical feeling for models in political economy and the social sciences in general as is evinced in his joint construction of a parlor game called So Long Sucker and a popular board game called Diplomacy.

In particular I remember the genesis of both the value and core solutions that are both landmarks in the study of games in coalitional form and in application. In formulating the Shapley value Lloyd wrote the axioms in part at Princeton and in part at his family's summer home in Sharon New Hampshire. He had invited me to join them for Thanksgiving. This involved an evening drive from Princeton and a 2 a.m. arrival at the observatory house at 60 Garden Street in Cambridge where chocolate chip cookies and instructions had been left for us on the stairs. We then proceeded the next day to Sharon. The time there was spent in individual work by all, with Lloyd concentrating on his value axioms. There was however a lengthy session on the porch overlooking the forest in New Hampshire with Harlow Shapley posing a simple problem to us. He observed that the trees were rocking to and fro violently and he conjectured that this motion was the cause of the heavy winds we were experiencing. Could we provide him with an experimental design to be able to prove or disprove this hypothesis?

It appeared to me that the Shapley value had an immediate application to voting in committee meetings and that it could be of special value in situations where different individuals had a different number of votes. We wrote a small paper applying the Value to committee votes and much to our surprise the American Political Science Review accepted this paper from two unknown graduate students in a very few weeks. The value has gone on to be a seminal tool in many other uses. The development and first applications of the core involved not only comments on the von Neumann Morgenstern stable set solutions and the mathematical work of Don Gillies but also an understanding of the connections to the work of Edgeworth and to the horse-market example of Boehm-Bawerk.

Sometime after the publication of the Value solution and after Nash's publication of his thesis results on the existence of noncooperative equilibrium points I had the opportunity to talk with Professor von Neumann. I evinced my enthusiasm for the use of the Shapley Value as a solution concept to apply to games in coalitional form. He argued strongly against both the value and the noncooperative equilibrium. Von Neumann felt that the formal mathematical representations used in the strategic and coalitional forms abstracted so much from the societies they were meant to represent that it was unreasonable to look for a solution that was a single point. Too much context has been left out to merit narrowing the solution to more than a subset of the outcomes. I argued that the Shapley value could be looked at as a natural benchmark. His decision to return to Rand in 1954 was based on considerations that he did not much like teaching but loved research. The Rand that he worked at in the 1950s and 60s was a very different institution from Rand in the 1980s and Lloyd left to join the mathematics department at UCLA.

In spite of not being directly at a university at the time his first de facto PhD student was Pradeep Dubey with whom he wrote many joint papers. His only joint book Values of Non-atomic Games

originally published in 1974 was with his colleague, and friend Robert Aumann, although I regard the book *Game Theory in the Social Sciences*, I published alone in 1984 as being based completely on joint work with Lloyd.

Although he was a member of the American Academy and the National Academy and held an honorary degree from the Hebrew University Lloyd was not a seeker after prizes or celebrations. At a meeting at Stonybrook held in his honor when asked to speak he commented that he felt this was like an end-of-summer, summer camp celebration where there was a prize for everyone, a prize for the slowest runner, a prize for making one's bed, and so on.

Turning to non-scholarly aspects of Lloyd's life, he was a highly competent pianist and an avid folk dancer both at Princeton and Rand. He was also a dedicated Kriegspiel, Chess and Go player. It is of note that while he was a good Chess and Go player he was superb and virtually unbeatable at Kriegspiel. He and his wife Marian were dedicated puzzle solvers. His family life was close. He and Marian had two Sons, Peter and Christopher and the family lived in comfort in the Pacific Palisades, complete with swimming pool and a guestroom heavily occupied by visiting scholars coming to work with Lloyd or by members of a large Shapley clan of relatives. The loss of Marian to bone cancer was a great blow to him, but he continued to live in the house they had bought in the 1960s until he succumbed to dementia.

This is possibly not a conventional Memoriam, but it is aimed at being a portrait of some aspects of a life of a great scholar and a personal friend.

Martin Shubik March 16, 2016