Role of Game Theory in Public Health

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Abstract: Game theory, a branch of applied mathematics has been utilized by researchers in various fields including health to arrive at practical solutions to contemporary challenges. The article aims to introduce the subject to medical fraternity in India and recommends that the theory should be included in the syllabus of post graduate students of community medicine so that future generations of public health experts are aware of the theory and its potential use to find tangible solutions to public health issues.

Key Words: Game theory; Public Health.

Introduction:
Game theory is a branch of applied mathematics that provides tools for analyzing situations in which parties make decisions that are interdependent. This interdependence causes each player to consider the other player’s possible decisions, in formulating his own. A game describes the optimal decisions of the players, who may have similar, opposed, or mixed interests, and the outcomes that may result from these decisions. Game theory has also been defined as a study of mathematical models of conflict and cooperation between intelligent and rational decision makers. Although practical use of Game theory can be found throughout history, the credit of its invention goes to John von Neumann and Oskar Morgenstern (1944). Eight game-theorists have won the Nobel Prize in Economics, and John Maynard Smith was awarded the Crafoord Prize for his application of game theory to biology.

Essential ingredients of a game
- Players are the decision makers in the game; a player can be an individual, group, institution or population.
- Strategies are the courses of action open to the players in a game.
- Payoffs are the final returns to players, which are usually stated in terms that are objectively understood by each player of the game.

Prisoner’s dilemma: An Illustrative Game
One of the most popular games is prisoner's dilemma. The police have arrested two robbers (players) whom they know have committed an armed robbery together. Unfortunately, the police lack enough admissible evidence to get a conviction. They however do have evidence to send each prisoner away for two years for theft of the getaway vehicle. The inspector locks the prisoners in separate cells and makes the following offer to each prisoner: if you will confess (strategy) to the robbery, implicating your partner, and he does not, then you will go free (pay-off) and he will get ten years. If you both confess, you will each get 5 years. If neither of you confess, then you will each get two years for the auto theft. Here, punishments can be converted into payoffs for each prisoner as 3 (free), 2 (2 years imprisonment), 1 (5 years imprisonment), and 0 (10 years imprisonment). The game can be represented as follows, where numerals written first in each cell reflects the payoffs to prisoner A, while payoffs to prisoner B are mentioned subsequently.

<table>
<thead>
<tr>
<th></th>
<th>Prisoner A</th>
<th></th>
<th>Prisoner B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confess</td>
<td>0,3</td>
<td>1,1</td>
<td></td>
</tr>
<tr>
<td>Refuses to confess</td>
<td>2,2</td>
<td>3,0</td>
<td></td>
</tr>
</tbody>
</table>

Assuming that both prisoners are rational, each player will evaluate strategies available to him by comparing his payoffs, for each possible action by his partner (now opponent). It is obvious that for player A the pay-offs are better if he confesses, irrespective of whatsoever strategy his opponent chooses. Obviously, he would confess. Prisoner B, meanwhile, evaluates his actions by comparing his payoffs and comes to exactly the same conclusion. In the PD, therefore, confessing dominates (called dominant strategy) the refusing for both players. Thus, both players will confess, and go to prison for 5 years, neither the best nor the second best payoff for either of them.

Game theory has been extensively used in economics, business and management. Political scientists, psychologists, biologists, sport coaches, military strategists and software programmers have made use of the theory to come to conclusions that are more beneficial in the real world. In medical sciences, the theory has been applied in almost all specialties including pharmacology (5), physiology (6) pathology (7), sports medicine (8), psychiatry (9), medical logistics (10), clinical medicine (11) and clinical decision-making (12,13).

Game theory and Public Health
The application of game theory in public health is most relevant when the actions of individuals or groups affect the health of others. On some occasions, individual or group strategies for betterment lead to inferior outcomes for the greater population.
Using game theory to model public health problems is not different from using it to model any other type of problem or decision-making scenario.

The Swamp: Extension of Prisoner’s dilemma

Consider a situation in which a swamp is located between two villages, Rampur and Sitapur. The mosquito breeding in the swamp is responsible for considerable morbidity due to malaria and other mosquito borne diseases. The problem can be remedied permanently by environmental measures ie filling the swamp. However, people of neither village are willing to act first because no incentives exist to take on the hard labour of levelling the swamp.

Table 2: The Swamp - Extension of Prisoner’s dilemma

<table>
<thead>
<tr>
<th>Village Rampur</th>
<th>Contribute</th>
<th>Not contribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribute</td>
<td>1,1</td>
<td>0,2</td>
</tr>
<tr>
<td>Not contribute</td>
<td>2,0</td>
<td>0,0</td>
</tr>
</tbody>
</table>

Similar to the game of Prisoner’s dilemma, the dominant strategy in this situation for villagers of both Sitapur and Rampur is ‘not to act’. The swamp survives; the worst outcome from public health point of view. Environmentalists can relate this game to innumerable real life situations. For example, is the attitudes of individuals, societies and even Nations towards the problem of global warming not akin to behaviour of Sita and Rampurians?

Rubella Vaccination: Another illustration of use of Game theory in Public Health is arriving at policy decision regarding Rubella vaccine. Rubella is a highly contagious childhood disease that causes relatively mild symptoms. However, the infection causes severe congenital defects, known as congenital rubella syndrome (CRS), if transmitted from a mother to fetus. Consequently, women have higher incentive to vaccinate against rubella than men do. While the vaccination protects the vaccinated, but also increases the average age of infection, which in case of rubella would increase the risk of CRS among unvaccinated females. To evaluate the interplay among these factors, the Game theorists developed an epidemiological model of rubella transmission and vaccination, and found that high levels of vaccination for both genders are most effective in maximizing average utility across the population by decreasing the risk of CRS. The results suggested that the rubella vaccination by males on voluntary basis would be far lower than the population optimum, if rubella vaccine were offered separately, instead of combined with measles and mumps vaccination as the MMR vaccine.(14)

Other areas of public health where game theory has been applied to obtain tangible solution to public health issues include role of social distancing in control of an epidemic (15), sustaining effective coalitions between public and private health care facilities (16), medical ethics (17), organ donation (18), bio-terrorism (19), medical-resource development (20), and improving acceptability of primary health care.(21) In general, Game theory provides a strong modeling device for public health professionals and illustrates the need of public intervention when the incentives of individuals impede progress for the group.

Conclusion

Community medicine specialists in India are generally unaware of Game theory and its potential use in public health and biomedical research. It is recommended that the subject of Game theory be introduced to post-graduate students of Community Medicine. It would empower the new generations of public health experts with this ‘tool’ that has the potentials to suggest logical solutions to public health issues. We, the community health educationists should realize that our pay-offs are better if the game is played early.

References