Examiner rated this a B

An analysis of Game Theory as a method to model dating strategies

To what extent can Game Theory accurately model and predict effective dating strategies?

Mathematics

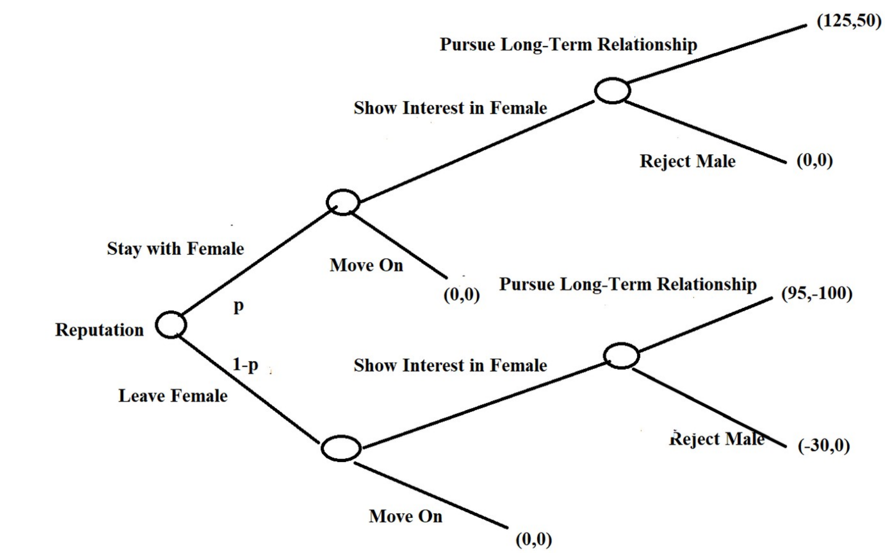
Word Count: 3,999

Table of Contents

Introduction

Game Theory is a way to use mathematics to find strategies that optimize payoffs gained by decision-making, something people do constantly. It is used by economists, psychologists, neuroscientists, and many others interested in decision-making, to model, plan for, and decide optimal outcomes for various situations. These situations are modeled as games where decision-makers are the players. Originally used by John von Neumann in the 1920's to search for a scientific way to play poker (Rosenthal, 2011, p. 3), Game Theory has evolved beyond card game strategy and into creating strategic models for some of the most complex and random-seeming decisions made by humans every day. One of the most interesting and complicated topics Game Theory has attempted to model is love. This refers to the process of vetting people to find a partner, dating that partner, then eventually marrying them, not the emotion itself. It is this process that is perfect for Game Theory analysis; there are two players (sometimes more if players are risky) who make decisions hoping to optimize payoffs for themselves using different, albeit not always moral, strategies with the entire relationship being the game. This sparked my interest because dating, at first glance, does not seem to involve much math but upon further inspection, there is more math associated with our love lives than one would guess. While effective in creating predictive models of behavior using payoffs and situational and strategic variables, Game Theory is limited because it relies on players to act rationally. In my own experience, people in relationships can tend to act irrationally and it is the conflict between math and humans that led me to ask **to what extent can Game Theory model and predict effective dating strategies?** To answer this, I will be using Game Theory models and contextualizing them to demonstrate relevant dating situations while also using statistical data to create claims about how the human dating process functions. I will show that while Game Theory can create effective models for general situations where humans play the dating game, the math alone cannot account for preferences, behaviors, and individualism. Before I delve into the question I need to address that emotions and behavior are variables that are extremely difficult, if not impossible, to model and pure mathematics provides a cynical look at this sensitive and intricate topic but, in the end, math does not care about feelings.

symbol	meaning	value



Cost/Payoff (M)	Cost/Payoff (F)
-X=-10	$-\varepsilon$+X= -1+10=9
-X=-10	0
Extravagant and Cheap: -X=-10	Extravagant and Cheap: 0
Valuable: -X=-10 Cheap: -X=-10	Valuable: $-\varepsilon$=-1 Cheap: 0

Figure 3. A Fool's Gold Game Tree Adapted to a Dating Game.

Unattractive Female (Cheap Gift and Identifies Correctly)	$P_M(1-P_F)(1-\eta)$= .25(.75)(.8)=.15	0	0	Both Players Unattractive (Cheap Gift and Identifies Correctly)	$(1-P_M)(1-P_F)(1-\eta)$ (.75)(.75)(.8)=.45	0	0
Unattractive Female (Cheap Gift and Identifies Incorrectly)	$P_M(1-P_F)(\eta)$= .25(.75)(.2)=.0375	Extravagant and Valuable: M_{UD}=5	Extravagant: F_{UD}=-40 Valuable: $-\varepsilon+F_{UD}$= -1-40=-41	Both Players Unattractive (Cheap Gift and Identifies Incorrectly)	$(1-P_M)(1-P_F)(\eta)$= (.75)(.75)(.2)=.1125	0	Extravagant and Valuable: $-\varepsilon$=-1

Table 2. Probabilities and Outcomes of the Courtship Gift Game

Base games and strategies

Courtship Gift Game

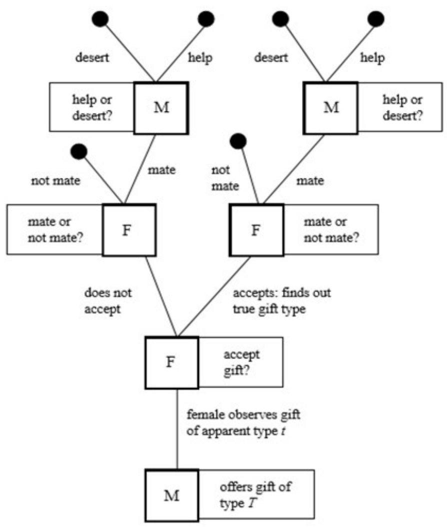


Figure 1. A Game Tree of the Courtship Gift Game. Adapted from "Costly but worthless gifts facilitate courtship" by P. D. Sozou, and R. M. Seymour, 2005 *Proceedings of the Royal Society B, Volume 272*, page 1878. Copyright 2005 by The Royal Society.

To begin, a game would define the players, usually a male (*M)* and a female (*F),* however nontraditional couples theoretically could be used. Romantic relationships usually start with shows of affection and other acts to gain the attention of another with a long-term goal in mind. Sozou and Seymour (2005) developed models of dating as a sequential game with mating as the end goal that can help set up premises about how dating games can be played. In these situations, the male and female act like opponents in an extended form game, shown in **Figure 1**, making decisions that directly influence how the opponent will respond. Prerequisite conditions are met before the game begins. Each player evaluates the other's attractiveness. The probability that each player will be rated attractive by the other, P_m for the male and P_f for the female, are known by the players due to prior and social knowledge. Premises were set that females would not mate with unattractive males and males would always desert unattractive females; therefore, positive payoffs for both players would only occur if both players considered each other attractive. The game proceeded with five steps: the male offers a gift, the female observes the gift, the female decides to accept or reject the gift, the female decides whether to mate, and if mating occurs the male decides to stay with the female or desert her. The costs and payoffs to the male presented in this game are if he finds the female attractive, what kind of gift he gives, if she chooses to mate, and if he decides to stay. If the female decides to mate the male gets a positive payoff no matter what so the primary goal of the male is to get the female to mate; however, it is important to understand that an attractive female gives the male a greater payoff ($M_{AttractiveHelp}$) than an unattractive female ($M_{UnattractiveDesert}$). The male can offer three kinds of gifts: cheap, which costs him nothing and is worthless to the female, valuable, which costs him X and has a value of X to the female, and extravagant, which costs him X but is ultimately worthless to the female. If no cost is created through gift giving then no risk is incurred on the male because even if the female decides not to mate his payoff remains at 0, as if he had not participated. The female's costs and payoffs involve more risk than the male, the greatest being deciding to mate and being deserted ($F_{AttractiveDeserted}$). The way the female gains a positive payoff is by mating with a male who stays ($F_{AttractiveHelped}$) or by accepting a valuable gift, or both. Because the male's strategy involves him always deserting an unattractive female, the female's strategy involves using the information given to her to decide if the male finds her attractive. Since cheap gifts cost the male nothing while valuable and extravagant gifts cost X, if he finds the female unattractive he will incur a negative payoff if he gives a valuable or extravagant gift because $M_{UD} < X$. In addition, it always costs the female ε to accept a gift. This means if the female receives a cheap gift she should decline and not mate, if she receives a valuable gift she should accept and mate, and if she receives an extravagant gift she should decline but still mate. However, a female's ability to identify gifts is not perfect, creating a larger chance for error in her strategy. The probability that the female incorrectly identifies a gift of type T is represented by η. Using the values in **Table 1**, the payoffs and risks for both males and females could be found for all situations that follow the rules of the game. Not all possible situations follow the rules of the game so these payoffs and risks are not in isolation, but are the only ones that follow a rational path. The probabilities these outcomes all add up to 1.25, which is greater than the typical 1, but this is because in some cases different situations follow the same path on the tree diagram because the tree diagram does not account for the exact type of gift given, T, and the type it is perceived to be. The female has much more at stake than the male because, while her greatest payoff is 19, higher than the male's at 10, she potentially can finish the game with a payoff value of -41, more than four times the male's worst payoff at -10. Both extreme payoffs for females are not likely, only 5% for the positive and 3.75% for the negative. When compared to the male's least favorable payoff, a collective 38.75%, and most favorable payoff, 10%, the male has a significant risk playing the game and is likely to come out with more negative payoffs than the female when the game is played many times, but because the female's range of possible payoffs is so large her risk is still greater if the game is played only once. All of these values are calculated in **Table 2**, to show that when vetting males as prospective partners for long-term relationships, females should tend to act cautiously due to higher risk while males should aim to play the game as few times as possible to be more likely to receive a net positive payoff over time.

Fool's Gold

The courtship gift game strategies rely on humans to act rationally and does not account for social repercussions of staying or leaving. It is also interesting to note that 75% of the time mating will not occur because the female will find the male unattractive and 56.75% of the time neither player will find the other attractive, making the payoffs close to, if not the same as if the game had never been played at all. This mirrors how in the real world, not all attempts at a relationship become one. However, the terms "mating" and "gift" do not accurately describe how first courtship encounters happen in most of the world. A "gift" could be considered a material item or an action that is used to get the females attention, and a more realistic way to view "mating" would be to consider it the point where a female decides to invest herself in the male and the relationship. To account for these components, the game of Fool's Gold, outlined in Rosenthal (2011), could be adapted to a scenario where the previously used extensive form game is considered a round of a larger game. The original game, shown in **Figure 2**, involves a merchant that mixes in fake jewelry with real gold pieces. A cost is created fixing up the fake pieces to look like real ones. The probability that the jewelry is genuine is given by *p* and the probability that it is fake is given by (1-*p*). In this scenario, a buyer approaches the merchant and chooses a piece of jewelry. The merchant knows if that piece is fake or real making the information in the game asymmetrical. The merchant then decides whether to sell the jewelry. If not, the game is over and there is no cost or payoff but, if he sells then the buyer must decide whether to buy. If the piece is bought and it is genuine the merchant receives a high payoff while the buyer receives a modest payoff. If the jewelry is genuine and is not bought there is no gain or loss but if it was fake, then the merchant loses the cost it took to fix up the piece of jewelry. If a fake piece is bought it is severely costly to the buyer and the merchant receives a high payoff minus the cost of fixing up the fake piece. The key to this game is the *p*-value. In a social setting where the merchant gets a fair amount of business, the more sales he makes the more defined the value of *p* becomes to the buyer. If the merchant sells a lot of fake items, his buyers will be unlikely to buy because they think the pieces are likely to be fake and the merchant will continually receive a negative payoff. Putting this game into a dating context, shown in **Figure 3**, replacing the male with the merchant and the female with the buyer, the situation can now represent an overview of the repercussions of the courtship gift game when it is played with different pairs of players, mirroring couples breaking up and dating other people. Over time, the culmination of how a player treats other players represents their reputation. The *p*-value is how likely the male is to stay with the female, the decision to sell is the decision for the male to show interest in the female, and the decision to buy is the decision for the female to pursue a long-term relationship. The more times the full game is played, the better defined and robust the *p* value becomes. This means while the male may gain a high payoff for showing interest and then leaving (selling fake jewelry), over time this gives him a low *p*-value and makes it less likely for him to gain any future payoff. Based solely on payoffs, the optimal male strategy when dating continuously is to decide not to show interest in a female if he does not plan on staying with her long-term, instead of aiming for the lesser payoff and potential cost involved with choosing to show interest in, but desert, a female. This saves his reputation and maintains a higher chance that he will gain his highest possible payoff. Since they can only gain a positive payoff if they pursue long-term relationships, females should pursue a them more often than not and only reject a male if his *p*-value is exceptionally low.

	Faithful	Cheat
Faithful	10 / 10	20 / -10
Cheat	-10 / 20	-5 / -5

Figure 4. The Payoff Matrix for Cheating. Adapted from *The mathematics of love* (p. 47) by H. Fry 2015 New York City, NY: Simon & Schuster, Inc. Copyright 2015 by Dr. Hannah Fry.

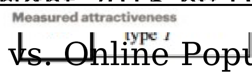


Figure 8. An Attractiveness vs. Online Popularity Graph. Adapted from *The mathematics of love* (p. 47) by H. Fry 2015 New York City, NY: Simon & Schuster, Inc. Copyright 2015 by Dr. Hannah Fry.

Figure 5. A Tree Diagram that Removes the Aspect of Post-Mating Consequences. Adapted from "Costly but worthless gifts facilitate courtship" by P. D. Sozou, and R. M. Seymour, 2005 *Proceedings of the Royal Society B, Volume 272*, page 1882. Copyright 2005 by The Royal Society.

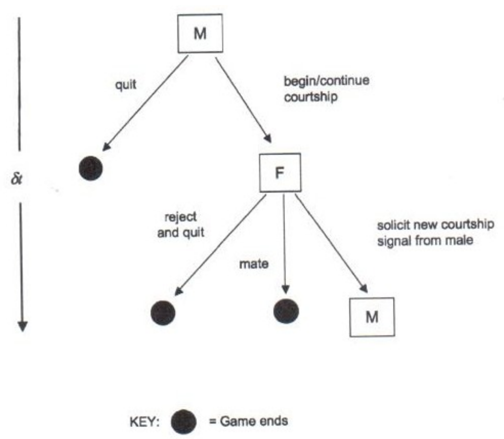


Figure 6. A Model of a Singular Round of a Courtship Game. Adapted from Duration ... R. M. Seymour, & P. D. Sozou, ... *56,* page 4.

The Hawk-Dove game

	Dove	Hawk
Dove	$\frac{1}{2}V$, $\frac{1}{2}V$	0, V
Hawk	V, 0	$\frac{1}{2}(V-C)$, $\frac{1}{2}(V-C)$

Figure 7. A Payoff Matrix for the Hawk-Dove Game. Adapted from *The complete idiot's guide to game theory* (p. 238), by E. C. Rosenthal, 2011, New York City, NY:
Penguin Group. Copyright 2011 by Edward C. Rosenthal

Subgames

So far, I have looked at minimally detailed ways relationships start and can play out. My analysis has looked at the players as opponents using one another, which is, hopefully, not usually the case. This is also a simplistic and hollow way to look at these situations. Life involves more complicated choices than whether to accept a gift before choosing who to date, both before and during a relationship. There are other significant variables, costs, and payoffs to consider and there is more to life than just tree diagrams. Each day brings new circumstances which when pieced together are the relationship in its entirety, like the concept of subgames. “A subgame is a game within a game”, (Rosenthal, 2011, p. 62), in this case the larger game being the relationship and smaller games being experiences that define it. Subgames simplify a relationship, letting players look at individual aspects and not just the big picture when making decisions.

Faithfulness

Considering a time cost added into the dating process, meaning there is cost for spending time playing a game and staying in long-term relationships, can explain why males might opt to desert a female, even if it means a lesser positive payoff. While dating her, he loses out on other potential payoffs elsewhere, which accumulate into a greater net payoff. In addition, to minimize time cost, both players can attempt to pursue multiple relationships at once, which carries its own risks. In Fry (2015) a payoff matrix, shown in **Figure 4**, exemplifies how this scenario can play out for both players. The numbers used are arbitrary but the idea it creates is important. Ignoring any moral standards, cheating gains twice the payoff from a faithful relationship. Getting cheated on creates a cost equal to the payoff of a faithful relationship. If both players cheat, they both receive a cost half that of being cheated on when deciding to stay faithful. The best option for everyone is staying faithful because then each player gains a positive payoff but, players can be greedy and seek self-benefit over cooperation and mutual reward. This uncertainty enhances risk because if players think the other is likely to cheat, they may see the best option as cheating back to receive a more favorable outcome, even if it is still costly. A player's behavior and trust between players are important to dating in general and apply especially to cheating. If there is little to no trust that a player will remain faithful, then cheating will always occur. In games, trust can be gained by using signals. Signals are pieces of information about a player's strategy given to the other player (Rosenthal, 2011). Signals become particularly useful when dealing with subgames because as more signals are used the more information the players have for when a new subgame starts. An example of a signal of loyalty would be a valuable or extravagant gift in the courtship gift game. It signals to the female that the male finds her attractive and acts as a motivator for her decision on whether to mate. In addition to positive signals, negative signals, called threats, are signals that imply negative consequences to the player receiving them, if a certain decision is made.

Finding a Type

Each time subgames repeats could be considered a round. Returning to the ideas presented in Sozou and Seymour (2005), where the courtship gift game is played, except the final step where the male decides to stay or desert is removed, shown in **Figure 5**, the purpose of the game changes and signals over the course of time become a factor. This model of the game “readily yields solutions in which extravagant gifts dominate over valuable gifts as facilitators of mating… [deterring] non-receptive females from acting as gold-diggers” (Sozou and Seymour, 2005, p. 1882). Here, the male has larger concern of being used. In this situation, assuming poor quality males have limited resources and cannot offer an exuberant amount of, if any, valuable or extravagant gifts, good quality males continually give significant payoffs to females if the game is played in rounds, shown in **Figure 6.** If valuable gifts are presented to the female continually and she continues to accept them with no interest in mating, the male loses X with every gift and a time cost (δt), shown in **Figure 6**, every time a round is completed while, the female only loses δt but gains X. When a female is skeptical of whether a male is good quality and must decide before mating, an extravagant gift will be enough to show the male’s type while also pushing away any females who wish to use a good male for resources without mating because they gain nothing from the relationship. This signaling is comparable to a simple vetting process. I feel it is safe to assume that humans do not want to spend their lives with someone they are incompatible with or someone who is going to use them. Because dating is a long and arduous process that undergoes different iterations depending on individuals' intentions, a game that requires each player to carefully consider their own intentions and desires and those of the other player over the course of time before proceeding, acts as an accurate way to find a life partner.

Hawk-Dove Game

Another factor that can affect the stability, quality, and duration of a relationship is arguments. Ranging from inconsequential to catastrophic enough to be relationship-ending, arguments have enough significance to be considered as another subgame. In the Hawk-Dove game outlined in Rosenthal (2011), the behavior of couples during arguments can be simplified into a payoff matrix, shown in **Figure 7**. Players can either play as a hawk, where they will act aggressively until gaining the full payoff (V) or becoming injured, which has a cost (C), or they can play as a dove where they feign aggression until the opponent shows further aggression and the dove backs down. If both players play as doves they both receive half the payoff, if one player is a dove and the other is a hawk, the hawk wins the full payoff and the dove gets nothing, and if both act as hawks then they both receive half of the payoff subtracted by the cost of being injured. This mirrors argumentation. Couples can argue until they hurt the relationship, or they can be understanding of one another and work things out peacefully, strengthening the relationship. If one just submits to the other, this effectively ends the argument, not doing anything to harm or help the relationship itself but, only the other individual gains the satisfaction of winning. Depending on the topic of the argument, the values of V and C can vary. The values also could potentially vary, due to different prioritization and subjectivity between players. If it is about where to go for dinner, small numbers like 1=V and 2=C would suffice, meaning that damage is relatively small if both players play as hawks but if over time this happens regularly then the cost to the relationship can build up. If the argument is on a greater scale, perhaps about one player's lifestyle choices or familial relationships, the numbers would increase dramatically and leave longer-lasting damage. This can mean receiving the silent treatment for a time or even potentially ending the relationship. This subgame over time is important to consider. The more it is played the more each player knows about when the other will use which strategy. If players both continually use the hawk strategy and do not adapt to the frequency that the other uses each strategy, then the cost will rise to a breaking point or payoffs over time will be skewed to favor one player in the relationship, giving the other incentive to end it.

Online Dating

With the use of the internet and technology, online dating has become a popular alternative to traditional methods. In theory, it makes dating simpler by putting what individuals are looking for into an algorithm and then seeing how well they match up with others. Here, compatibility and attractiveness would be the variables that signal a player's quality in a relationship. It would seem that these simplified variables would make online dating better for Game Theory analysis but this may not be entirely true. First looking at attractiveness, in **Figure 8**, there is not a strong correlation between how attractive others think you are and how popular you are when dating online. This is because people shy away from those who are objectively attractive due to the higher chance of increased competition and in turn make the subjectively attractive people more popular (Fry, 2015). Compatibility ratings also tend to be limited. From Rudder (2014) the online dating site, OkCupid experimented on its users, giving them false match percentages. A pair that was given a 90% match that was true went on to converse past one message 20% of the time. In addition, pairs that matched 90% but were told they only matched 30% pursued longer conversations 16% of the time. Surprisingly, a pair that only had a 30% match but was shown 90%, had conversations past one message 17% of the time. This shows that dating algorithms have minimal accuracy in predicting actual compatibility and the results act as a self-fulfilling prophecy. This is not to say that online dating has no merits. According to Statistic Brain (2017) relationships that start online that end in marriage date 23.5 months less than relationships that start offline. This could mean that online dating can simplify the early vetting process that Game Theory outlines making it last less rounds and in turn less time.

Conclusion

While Game Theory may be a useful way to use mathematics to analyze behavior, it only provides a little order to a lot chaos. In my research, it was clear that to create quantifiable and accurate models of an individualized relationship scenario would take extremely extensive research, calculation, and thought. Marriage, in many cultures, seems to be the best way dating games can end but marriage is not the goal for everyone and divorce is also a factor to consider. Also, individuals cannot map out a full game because they do not know when the game will end, so the game of the full relationship is not possible for someone to find for themselves. This leaves looking at dating generally, only being able to look at base scenarios that provide little detail. The lack of emotional and moral standards makes the task of modeling human decision-making difficult, because math does not factor in emotions and morals unless they can be used as quantifiable variables. Relationships can take twists and turns that Game Theory cannot predict because humans have infinite possible reactions. Most of them are not rational and Game Theory relies on rationality. While these models may be simplistic and not provide much individual guidance, it does give a clear sequence that relationships can take. General models can work as a starting point to optimize a budding relationship but individual variables like personal motivations are left out. Also, cooperative games that reward mutual benefit over self-benefit more accurately mimic a healthy relationship but not all relationship scenarios are cooperative. Game Theory can simplify and create representations that outline dating but because of so many behavioral, cultural, and emotional variables, its accuracy is limited to only general terms. Getting another’s attention and interest through gifts and actions, the damage or strengthening arguing can do, and so on, all act as a starting point for understanding how to make the dating game work for an individual. These methods may not be perfect but neither are the relationships they attempt to model.

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