Chapter 16

Game Theory as Psychological Investigation

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1. Introduction

Over the course of history mathematics and science have become increasingly entangled with one another. This has been especially true in the physical science wherein mathematical derivations have resulted in subsequent experimental pursuits. While the social sciences have relied on mathematical descriptions in recent generations it was not until the more general employment of game theory that mathematical modeling became itself a directive tool for subsequent evaluation as it had so become in the physical sciences, most prominently perhaps in high energy physics. This chapter shows how game theory forced upon the social sciences new avenues of investigation. It also shows that once those investigations were fully underway they in turn forced new considerations on the practice of game theory modeling. This boot-strapping dynamic between mathematical game theory and social science represents a novel turn in the relationship between the two disciplines bringing their relationship more into parallel alignment with what has long existed between physical science and mathematics.

Science and mathematics travel along coincidental paths. Just how coincidental is a source of perennial speculation and argument among sociologists, philosophers and historians of both science and mathematics. If the paths math and science travel are only coincidentally linked then neither serves as foundation or guide for the other. On the other hand, if the paths are destined to be linked in some fashion then the affiliation between the two is more than merely coincidental. Any answer to this query seems necessarily to raise the question of whether either, at least in its modern form, can exist without the contemporary development of the other. Any effort to address this issue inevitably prompts consideration of the ageless question of whether mathematics is invented or discovered.

Early explanations of the natural world can be put forward in strictly naturalistic terms common to the researcher's native tongue or in some cases scholarly language such as Latin or Greek in the West and Mandarin in the East. The science of antiquity was largely free of any necessary bondage to mathematics. Admittedly as soon as early cosmic observers in both the East and the West began tracking the heavens something akin to early arithmetic appeared as did some rudiments of geometry. Nonetheless, some descriptive sciences such as biology, physiology and psychology advanced for many centuries without necessary dependence on mathematics. Even well into the nineteenth and twentieth centuries scientists known as naturalists did amazing and properly described scientific work without much reliance on heavy mathematical machinery. Names that immediately come to mind are Charles Darwin and E. O. Wilson. Of course today the biological sciences are as dependent on the power of mathematics to aggregate the data of scientific thinking and organize inferential patterns as were the early cosmologists and contemporary high energy physicists [1]. Still the question remains: are the two paths necessarily linked?

Mathematician extraordinaire, G.H. Hardy spoke dismissively of his protégé, Norbert Weiner when asked what he thought about Weiner's applied accomplishments. Hardy said in no uncertain terms that Weiner was no mathematician! Weiner, Hardy complained, applied mathematics [2]. *Real* mathematicians Hardy declared, never leave the pristine purity of the number world itself. They don't use the beauty of mathematics to do the yeoman's work of science or engineering. A reporter asked Hardy why then should anyone do mathematics if, as it seems from what Hardy was saying, that it has no practical pay-off. Hardy's response was almost zen-like to anyone not a mathematician. Hardy said, "Because it's such a damn good sport! [3]"

Hardy's declaration makes clear that at least one noteworthy specialist in number theory sees no need to tie mathematics to anything in the sensuously detectable world of science or the daily life of ordinary humans. Mathematics or at least that domain of mathematics that Hardy was most interested in, depended in no way on the shifting sands of human observation and empirical science [4]. Contemporary science may need mathematics but there are areas of contemporary mathematics that can stand well apart from the fortunes and misfortunes of contemporary science.

To a mathematician like Hardy and logicians like Kurt Godel [5], Hao Wang [6] and Alfred Tarski [7], mathematics is something to be discovered. To these thinkers, mathematics could never be conceived as a mere game or a simple approach devised by shepherds for keeping track their flocks as some empirically-minded theorists have opined [8]. In any case however independent mathematics and science may be distinguished from one another as separate disciplines there can be no doubt that mathematics has often advanced the agenda of the various sciences. Not only has mathematics proved to be a wonderful tool for aggregating data and then organizing it in ways leading to prescriptive efficacy but inferences that appeared from various mathematical tinkering have often prompted fruitful scientific speculation. This of course has been especially true in higher energy physics and cosmology. For example, Paul Dirac's use of David Hilbert's infinite dimensional space led to unexpected and fruitful direction for empirically based theory. And, Dirac accurately predicted the existence of positrons on the basis of mathematical calculations alone [9]. And more recently this mathematical showing the way in empirical science was replicated again in Richard Feynman's sums-over-all-possible-histories.

In what follows, I will discuss how the coincidental crossing of paths in the social sciences of decision-making and mathematical game theory led to fruitful excavations in the psychology of decision-making and mental life, especially in the case of humans [10].

Blaise Pascal is generally recognized as the father of decision theory and judgment – making under conditions of uncertainty [11]. Shortly thereafter Thomas Bayes gave respectability to the practice of employing prior probabilities to continually adjust and update predictive calculations [12]. John von Neumann gets well – deserved credit for expanding this work into a theoretical approach for identifying strategies that increase the likelihood of decision-makers under conditions of uncertainty optimizing expected value (EV) in real world decision-making. Just as Pascal was attracted to the intrigue of investigating decision-making under conditions of uncertainty in playing dice games, in the 1920's von Neumann became enamored with investigating decision-making under conditions of uncertainty in poker where, in addition to the uncertainty of probabilistic distribution of card sets, each player employed differing bits of information of other's strategic style [12 p. 42].

Where Pascal relied on statistics alone for answers and Bayes opened the door to ready revision of planning estimates, von Neumann proposed a broader and more robust set of tactics for capturing relevant information explicitly for planning purposes. Von Neumann extended the reach of employable planning information into quantifiable estimates of the very mindsets of fellow players [12 p. 89-96]. The trouble was however that he didn't sufficiently appreciate the distinction between facts of the external world and facts of transient, human psychology.

Initially von Neumann was struck by the fact that unlike closed systems of transparency such as chess, checkers, Go, Tic Tac Toe and other like games, in poker there is a disproportionate distribution of information.

Information for von Neumann was all of one sort. It was a set of rule governed symbols. Once one knew what symbols to employ, formal structures made it possible to derive conclusions. The trouble is however, in poker, the disproportionate distribution of information also suffers from a differential reliability of evidence.

The epistemic challenges of securing reliable evidence are not all of one sort. Gaining knowledge of a somewhat static external world (at the macro-level of sensuous human experience) is different from gaining knowledge of the shifting sands of individual mental life. No player knows with certainty what cards other players hold. This is an epistemic challenge focusing on the facts of a momentarily static, external world. In contrast, no player knows what each other player anticipates his fellow players to do in a given set of circumstances. No player knows the strategy each other player may have in mind for playing this particular hand given the particular set of cards the player holds. These are both matters of transient human psychology about which far too little was known at the time of von Neumann's initial efforts at game theoretic modeling [13].

The first epistemic shortcoming referred to in the paragraph above is about the world as it exists external to the mind of any given player. The second and third epistemic shortcomings above referred to the psychological, more specifically, the mind set of other players. Nonetheless, depending on the previous betting patterns of each player in previous hands (and continually aggregating that information through the process of updating prior probabilities) there is important information available which together with a probabilistic assessment of the competitive strength of the hand one currently holds and an estimate of the strength of the hands held by others that *should* make strategizing more efficient than if one were to rely on the probabilities of certain card assortments and their distribution among the number of players in the game alone.

Von Neumann imagined using mathematical matrixes to sort and arrange probabilities of outcome to discount the EV of payoffs and determine player utility for each outcome in order to anticipate likely plays for each player [14]. With this mathematical tool in hand, along with reasonable estimates of the uncertainties referred to above, he imagined that an optimally effective winning strategy could be identified. Such a strategy could then lead to a generally profitable strategy over a run of playable hands. Of course, as the other authors of this volume will surely attest, the range of uncertainty in the game of poker is too vast to allow for the efficient application of game theoretic principles. This is still as true now as it was in von Neumann's time. It certainly is no surprise that von Neumann gave up his work on game theoretic reconstructions of poker playing strategies [14].

Von Neumann eventually moved beyond his playful distraction of subordinating poker to game theoretic principles. He along with the economist Oskar Morgenstern turned to human decision-making on the largest scale of systematic competitiveness (even though for illustrative purposes they limited examples to mostly two person games). Their large picture modeling emphasized zero sum and constant sum games. This emphasis probably was influenced by the post-war atmosphere, the increasing focus on central planning and strategic and tactical, Cold War worries. From these decision-models Neumann and Morgenstern produced a favored strategy for decision-making they called the maximin strategy [15].

Von Neumann and Morgenstern's maximin strategy became a competing paradigm to other schemes of classical economics for analyzing economic exchange and other forms of strategic behavior. This early work of von Neumann and Morgenstern has since become the classic statement of game theory in an ever expanding variety of game theoretic contexts to which all writers since have felt some obligation to acknowledge. The von Neumann and Morganstern term maximin is a bit of conceptual apparatus that is still in use though it has been shown that all maximin strategies can be reduced to a special case of minimaxing [16]. The maximin/minimax theory is also referred to in aggregate fashion as "satisficing strategy" [17]. For purposes of economy I will henceforth use the term satisficing to refer to either. Roughly speaking the strategic objective of minimaxing is to minimize risk while maximizing utility, to maximin, the strategy is to discount utility proportionately to manage acceptable risk. In short, both attempt to make the best of a risky and uncertain situation. Together minimax and maximin are strategies. Satisficing is the hedge fund strategy of decision theory.

The ambition to extend their early work to the largest scales of decision-making is evident in Morgenstern's later work [18] and also in von Neumann's work as Chair of the Atomic

Energy Commission [14]. The innovative mathematical applications of von Neumann and Morgenstern opened up vast new vistas of prescriptive decision theory [19] and, as will be demonstrated below, made possible new horizons in psychological and other descriptive social sciences.

Even before the computer and imaginative efforts in artificial intelligence and cognitive science, von Neumann and Morgenstern, along with those who shortly followed them, showed ways for illuminating much of the mystery of human mental life. To a brilliant mathematician like von Neumann the mathematics of game theory was not much of a challenge. Yet von Neumann's work in game theory remains his most lasting contribution to the sciences. Not only is game theory used in economics, international trade, military strategizing, and business operations at every level it is now also used to illuminate various evolutionary models in biology, anthropology, archaeology, sociology and psychology all in addition to economic theory [20 - 24].

As with any well thought out application of mathematical protocol, game theory depends upon a few simple and well-articulated base line assumptions. These assumptions address the nature of decision frames, their constitution and representation in formal models and the appropriate range of game theoretic applications.

At the time of von Neumann and Morgenstern's early work there were three basic assumptions common to economics and behavioral psychology. These assumptions were, first, humans are self – interested. Second, humans are rational. And third, humans are self-determining consumers. To these three, Von Neumann and Morgenstern added five more:

1. All outcomes can be known to varying degrees of certainty
2. Player information is often incomplete
3. Utilities (measures of one's relative gain) can be measured
4. The utilities of all outcomes when the other assumptions are met can be discounted and summarized in a single quantity (EV).
5. Some games are competitive (zero sum games), some are constant sum games and some constant sum games and non-zero sum games often favor dominant strategies whose equilibrium invites cooperation as an attractive strategy[25 p. 88-89; 26].

Game theory was employed almost immediately for strategizing by various governments around the world perhaps most notably in the United States at the government's quasi-private think tank, the Rand Corporation [15]. Decision-making models were driven less and less by simple cost/benefit analyses and weighted outcome averages and more on the basis of;

1. likelihood of outcomes
2. integrated with *perceived* utility and then…
3. derivation of an EV for each outcome

Of course, even with such integrated summaries at hand personal willingness to act on the basis of EV reflects the temperament and sense of responsibility of the decision maker [10, 13, 21, 27, 28, 29]. Witness for example the disproportionate risk the poor undertake to buy a lottery ticket when the EV to them is especially low. There is no secret about how little chance anyone has of winning a lottery [30 p.163 - 175]. Wealthy people can afford greater risk yet they tend to find the cost of lottery investment a poor buy. In contrast, many of the poor for whom the relative cost is so much more, imprudently absorb the risk time and again. This social phenomenon truly appears in sum to be a tax on ignorance. EV and human psychology are often in tension that tension illuminates both the social sciences and the challenges of exhaustively modeling best decision-making practices. Best to whom and under what circumstances remains a live challenge to normatively –driven, decision theorists and descriptively – driven social scientists alike [31]. How much individual agents understand and how much they are willing to satisfice to achieve acceptable results within a specified problem frame continues to be a subject of much uncertainty [32]. No mathematical theory can determine how risk aversive a decision maker might be or should be [33]. The mathematics can show only that integrated summaries spell out the discounted EV of available bets [34].

The enormity of this tension and the challenges it represents can perhaps be most vividly imagined in the context of the decision at Los Alamos during WW II to test detonate the first atom bomb. A major player in this decision was John Von Neumann [15]. In this case, von Neumann together with Stanislau Ulam was assigned the task of calculating the largest scale bet ever made in the history of humankind. Specifically they were assigned the task of figuring out the odds that when the first atom bomb exploded only the intended atoms would fission. In other words they were to calculate the odds that under the problem frame of detonation other surrounding atoms would not be drawn into an unrelenting process of nuclear destruction [35]. This calculation could not have been responsibly derived from formal probabilities alone or even some frequency study of previous atomic behavior under controlled conditions. At the very least subjective probabilities had to be utilized by the decision-makers and most likely they were utilized in some game theoretic fashion. Surely von Neumann's twenty years of game theory reflection influenced his calculations and subsequent recommendation to General Paul Griffiths. One can only wonder how small the odds of universal destruction ought to be in the mind of the great mathematician in order to recommend a properly satisficing go-ahead for the initial detonation.

While there is insufficient public information describing what happened at Los Alamos during that period it is nonetheless likely that game theory played a role [15]. In any case whatever reasoning was pursued by the mathematicians, generals and physicists at the time, game theory today could effectively model the potency of the actual, social and psychological forces presumably then at play [36]. Such modeling can prove illuminating in understanding ever more about the real process of human decision-making under conditions of uncertainty [37].

Throughout WW II game theory and Bayesian statistics both became more fully utilized at the highest levels of organizational decision-making [38 p. 185 – 220; 39 p.58-60]. At the same time game theory was becoming more widely embraced by academics and major decision-makers alike, it was also becoming apparent that there were problems to be solved in the utilization of these new mathematical tools in the ever increasing array of phenomena they were being used to model [39]. The focus in this brief chapter is game theory so there will be no further discussion of the problems some statisticians and other theorists found with the grounding or utilizing prior probabilities in Bayesian deployments. Such matters are important to the current topic but an adequate treatment would require far more attention than one can responsibly undertake in a single chapter.

In game theory, three major realms of difficulty emerged. First, settling issues of how risk aversive a given decision-maker *should be* in specific contexts proved increasingly intractable to any sort of formal analysis [40 - 41]. The more aggressive the efforts at formal analysis, the more evident it seemed that the psychology of human nature would in the end adjudicate matters of appropriate risk aversiveness for an individual or a group [42 p.94-110]. This realization was significantly responsible for prompting further psychological excavation into human motivation.

Second, less than a decade after publication of von Neumann and Morgenstern's *Theory of Games and Economic Behavior* [25], John Nash [43, 44], Richard Selton and John Harsanyi [45] showed that the psychological assumptions of classical economics and behavioral psychology led to unavoidable paradox. Expanding on von Neumann and Morgenstern, Nash alone and Selton and Harsanyi together demonstrated that given the current assumptions of game theory the most rational course of action for all players in any competitive game (zero sum or constant sum) was to follow a course of action that secured an equilibrium in EV among all players [46]. When every player recognizes an acceptable EV in a common strategy, that strategy dominates over all other choices for each and every player. Dominant strategies (whether mixed or pure) benefit everyone and impose no undue loss on anyone [47]. This platitude sounds too good to be true. If such dominant strategies could be identified for all human interactions game theory would have shown how peace and decorum can be realized throughout the world in every way [48-49]. All social problems would be reduced to simple puzzles in game theoretic modeling. Plato's philosopher kings would have been found but they would be mathematicians and not philosophers. But as Nash, Selton and Harsanyi all realized, much of the social world is not amenable to such modeling.

Somewhere in the Government-funded Rand Corporation think-tank, there emerged the puzzle of the most famous game in all of game theory, namely, the Prisoner's Dilemma (PD) [15]. Nash is often attributed with its first formulation but there seems to be some controversy over who the actual originator was [49]. Other names mentioned are Merrill Flood, Melvin Drescher and Albert Tucker [13 pp.5-6]. Nevertheless, that the PD became the source of much contested theoretical musings at Rand and then later in the specialist journals is undeniable [50].

The issue illustrated by the PD is that it leads to a paradox given the standard assumptions of classical economic and behavioral theory [49, 50]. The issue was not seen as a matter of psychology. Rather theorists simply noted that people might vary as to what they favor either individually at the moment or, over time (though those stipulations vanished as "time" has become a recognized issue in subsequent theorizing). The technical issue was that the classical model led to a disparity between securing optimal utility for each player despite the fact that one could derive a satisficing equilibrium that was demonstrably less than optimal.

Game theory was intended to show that by formalizing decision spaces and applying game theoretic principles, decision-makers could illuminate in every case the most rational course of action that by definition ought to produce the highest level of satisficing utility for each and for all.

Although some game theorists continue to deny that the PD ends in a paradox they represent a very small minority of thinkers [51]. This minority insists that the alleged paradox simply demonstrates that sometimes the only strategy open is not a minimax risk aversive strategy but rather a maximin strategy wherein all players wind up losing significantly but that a rationally derived equilibrium is achievable nonetheless and so game theory's value remains unimpeachable as classically portrayed [52]. This convoluted effort to sustain the distinction between maximin and minimax and derive a dominant strategy remains generally unconvincing to most [51]. Instead the paradox of the PD has become importantly informative in forcing theorists to reconsider the preferences of actual players in real world PD situations [33]. In doing so, game theory has led to the creation of a whole new dimension in the social sciences known now as preference theory [53].

Typically the scenario of the PD looks something like this. Two criminals are caught shortly after a robbery they committed. Authorities place each suspect in a room separate from the other and offer each criminal individually a deal to ease the authorities' way to a conviction for either one or both the suspects. For convenience, name the criminals Donald (row) and Rosie (column). Each is told that if he or she testifies against the other (defects) then the other person will spend ten years in prison and the defector will be released (0 years in prison). Counsel for each cautions their respective clients that if each defects then it is likely that the court will put each of them away for five years. Counselors' for each advise additionally that if each of the accused remains silent (cooperates) the authorities already have enough evidence to put away each of them for two years on a related but far lesser charge. Neither Donald or Rosie nor, their respective counselors, may consult with the other or with the other's counsel. Finally, the authorities' demand that an immediate response to their offer. Assuming each person is self-interested and rational, the choice seems obvious as illustrated in the matrix below.

		Defects	Cooperate
Donald	Defects	5, 5 (I)	0, 10 (II)
	Cooperate	10, 0 (III)	2, 2 (IV)

Table 1. Rosie

If Donald defects and Rosie cooperates by remaining silent then Donald loses nothing (cell II). The same possibility is true for Rosie if she defects and Donald cooperates by remaining silent (cell III). Neither Donald nor Rosie know what the other will do. However, by stipulated assumption, they each "know" that people are rational and self-interested and moreover there is no reason to think their counterparts in this situation are any different than they themselves and other rational people. Each is also aware that the other criminal may be thinking the same way about them and so the only way to avoid getting suckered into a ten year incarceration is to defect and expect that the other will too (cell I). In this case each will lose five years of life. Given the assumptions of both rationality and self-interest this determines a dominate strategy that is to say, an evident "right" choice. Yet something seems strongly counterintuitive here.

Clearly there is no likely outcome that optimizes Expected Value (EV) for either of the criminals. The EV for both, as noted above under the current set of assumptions is an EV of ten lost years for the two together (five years for each). Yet in cell four there is a payoff of four lost life-years for the pair (two years for each). This is clearly the best option for the pair. But again, given the standard assumptions of classical von Neumann and Morgenstern game theory, there is no way to get there [54]. The PD truly represents a paradoxical situation as most scholars allege and thus von Neumann and Morgenstern's game theoretic satisficing strategy is a poor tool for identifying a dominant decision-making strategy under such situations [55].

If the von Neumann and Morgenstern assumptions about modeling are changed, then the preferred equilibrium can be derived [52, 56]. For example, if Donald and Rosie *know,* to some high degree of certainty, that each has a strong sense of loyalty and *prefers* to demonstrate that preference above nearly any other rewarding outcome. The problem frame shifts significantly [57]. In addition, if each player values (assigns high utility) the well-being of the other at least as much as each values him or herself, then each can count on the other's silence. This new bit of surmizeable knowledge shifts the problem space even further. With the new assumptions in hand, and the problem context re-framed as a result, the dominant strategy is now the strategy that secures the EV in cell II. Of course now it seems that securing the best decisions in life is no longer a simple mathematical problem but is dependent on accurate psychological observations as well. The mathematical modeling led to the need for empirical investigation if applications to the world were to be truly productive. Coincidentally, the empirical investigations of psychology and other social sciences now had a robust and productive new direction to explore thanks to the revelations of mathematical game theory efforts at application.

But how does one ever know – even to a reasonable degree of certainty – that people in general or another person in particular embraces noble or at least cooperative preferences in a steadfast way? What counts as a *reasonable* degree of certainty? As with von Neumann and Ulam's recommendation regarding detonation of the first atomic bomb such considerations in the end are normative as more a matter of philosophy than empirical science or mathematics. Yet the empirical social sciences can speak to the likelihood that people in general address certain ranges of problems in fairly predictable ways and this gives each player more information under conditions of uncertainty than a fly – by – the pants guess. In addition, each player may be able to augment that situation by personal knowledge of the other player. This Bayesian updating of subjective probabilities improves the betting odds of each player at every step of the way. This is no small accomplishment. As Ken Binmore so wisely observes, "Only in a small world, in which you can always look before you leap, is it possible to consider everything that might be relevant to the decisions you take [41 p.139]

The only way to get a better grasp on human "problem-framing" tendencies is to do scientific work into the actual preferences of human beings. Psychologists and behavioral economists must measure the variability of sustaining preferential strength under various conditions. For game theory to be efficient in PD - like situations adaptive correction of previously assigned, prior probabilities, that prove inconsistent with the material facts of social interaction how much more need to be known about human psychology than people like von Neumann and Morgenstern thought necessary.

Two games devised for more deeply mining human preferences and problem-framing practices are the Ultimatum Game and its variant, the Dictator Game. Each game creates an empirically measureable construct in which people have to make a choice often at some sacrifice to self and with no immediately apparent reward. The evidence overwhelmingly demonstrates that people will sacrifice to punish a perceived unfair, non – cooperative defection [40]. Whether or not people engage in such apparently altruistic behaviors intentionally because of being hard-wired to cooperate and punish defection by evolution is yet to be determined. What no longer needs determining is the fact that people act on other than simple self – interest when framing a problem space. Other natural and wide spread human preferencing habits are now being identified and taken into account in developing more exhaustive game theoretic models and decision –processing strategies [45]. Without going into further detail, suffice to say that the general consensus among empirical researchers is that the PD in addition to games such as the Ultimatum Game and the Dictator Game demonstrate that humans have a tendency to act somewhat altruistically and are sensitive to violations of what they take to be fair play in practices of distributive justice [46]. It is interesting to note as well that empirical studies based on such games show that cross-culturally people are likely to accept some cost or sacrifice willingly to punish a player (whether familiar to the player or not) who makes little attempt to be cooperative with others [36].

When the constraint of self – interest is loosened and weighted appropriately along with other identified preferences, a more comprehensive picture of players' desired payoffs and likely strategies emerges making equilibrium strategies more evident as the dominant strategy for each player [50]. Moreover, as Bayesian revisions are made in light of assessments of the other players' weighted preferences and developing information set, the problem frame suggestive of an appropriate game theoretic matrix can be more approximately fitted to the real world state of affairs defining an applicable game [55]. This is particularly true when the real world is in flux or when an unlimited round of plays in the future is anticipated by the players. For example, branching tree decision models developed to reveal these sorts of anticipatory decision factors as well as other evolving relevant determinants of outcome that become evident as the sequence of subsequent decisions prompt further review to sustain equilibrium. This sort of application is effectively illustrated through the employment of the Beauty Game.

The Beauty game is a variant of the strategy recommended by the character of John Nash in the movie A Beautiful Mind. The Beauty Game shows that identical game structures can be nested within a larger game. While each problem space looks similar in character when taken one by one, when the nested structure is taken into consideration as a whole, the structure of the problem frame itself may shift into a different sort of game. Through use of a decision tree the nesting of games is revealed. For example, as I show in my discussion of the Beauty Game elsewhere [58] a cooperative non-zero sum game can quickly shift into a zero sum competitive problem frame. When the set of nested games are seized upon and reconstructed as fragments of a much larger problem frame identifying time and shifting identifiable preferences as factors realigning possible pay – offs in a serial fashion. Equilibrium achieved early on can be destabilized when the sequence of rounds can be shown to have a determinate limit. Thus backwards induction may reveal earlier distributions of EV are not as satisficing to all as may have been first perceived. (No matter how the game is played, not everyone can have the one uncontroversial "most beautiful girl")[58].

Beyond the evident paradox in the PD referred to above, the third difficulty that emerged for game theory was that psychological preference theory was impoverished in the 1950's [13; p. 1-6]. There was little for game theorists to draw upon when attempting to apply game theory to the actual world of daily life and especially in the more mundane aspects of daily living. Many real life situations seem to fold into PD matrix distributions. If so and if people recognized paradox after paradox then cooperative problem-solving efforts would run aground so often that human rationality would become generally discredited. The fact that humans somehow seem to navigate their way through the many PD situations they face as a matter of routine suggests on the other hand that there was no linear processing going on but rather just random or emotionally charged and unpredictable acts leading people through the PD problem frames. Or again, under the classical model people inevitably face making decisions that look optimally rational on the surface except the uncontroversial dominant strategy delivers less EV than could evidently be achieved.

Too many PD situations as in the Beauty Game, left an abundance of goodies on the table. Empirical researchers surmised these goodies could be distributed in an optimally efficient fashion. (The Beauty Game represents a further difficulty because the reward of the one most beautiful girl cannot be distributed and satisficing strategies do not work as long as the unit of reward she represents stays unimpeachably intact. In the movie, A Beautiful Mind, all the suitors satisfice but, only at the cost of removing the most beautiful girl from the pool of EV. And as I explain in the Beauty Game, the master strategist by removing himself from the first round of play may have masterminded a super game which remains satisficing to all only so long as no one catches on to his ploy to secure the greatest EV for himself in a discrete subsequent round of play in which only he and Beauty are left. [58]) Classically derived, dominant strategies appear on the surface to be insufficiently potent. For game theory to be of value in the nearly ubiquitous realm of PD situations more must be learned about actual human preferencing practices [55].

Psychology and the other social sciences had to develop insights that mathematical modeling by itself could not achieve. Mathematicians had to await the insights of social scientists studying preferencing to advance their own efforts to improve game theoretic modeling. Once again the coincidentally entangling paths of mathematics and science became evident with neither discipline wholly dependent upon the other. Instead game theoretic applications required mathematics and social science each to boot-strap further progress on results achieved by the other.

Thanks to the game theoretician's need for further insight into human preferencing empirical investigation into human motivational action by social scientists of every stripe accelerated. The result of the subsequent growth into human preferencing studies and related heuristical practices is that game theory was able to extend its range of apt application throughout the social sciences extensively and then ranging into fields such as business, finance, evolution and population genetics [31]. Together game theory and psychology excavated into mental life more than previous behavioral stipulations and methodologies would have ever allowed [13].

As noted above, a range of PD games confront people every day. Game theory is not an esoteric study for parlor mathematicians alone. This merging of the mathematical and the social sciences has enormous value in understanding the practical life of most humans every day. Consider when you are driving on a fast-moving but heavily congested freeway and you and another driver (player) want to change into the same lane in what seems to be a relatively rare opportune moment. This is a zero sum game at the moment when the problem space is defined narrowly in terms of one player's success guarantees another player's loss. But in the real world of driving, different drivers have different purposes and different heuristical practices they are likely to employ. How much information can a deliberative player have about the real situation he encounters? How should the different fragments of information be weighted in near spontaneous fashion? How best should the game theoretic driver weight her own EV in securing a move into the fast lane? What are the probable outcomes of any move on the part of each driver?

Once one moves from the narrow defining of the problem frame to formulating a game matrix that ostensively captures real world possibilities as well as identifying an optimal strategy. The lane changing situation is clearly a PD environment. However, practical application of PD technology constitutes a severely time – discounted, problem frame. Consequently, for all practical purposes game theoretic strategizing under such constraints is ill-advised. Drivers probably do best what they are already inclined to do and rely on Kahnemann describes as System 1 thinking [40]. Having acknowledged the prescriptive poverty of game theoretic thinking in such practical applications it may still be profitable for social scientists to observe large numbers of driver behavior under such circumstances and model such behavior to reveal whatever can be known about such driving strategies in general. Indeed, if researchers learn more about statistical patterns common to such contexts and survey driver preferencing patterns perhaps safer freeways, automobile safety additions and driving instructions might be derived.

Employing a more exhaustive set of assumptions allowing for individual preferencing avoids the paradox of the PD [55]. Of course, the challenge then becomes for social scientists to excavate into human mental life and identify relevant information about the preferences of human actors.

The practical advantage of game theory to decision – makers is obvious; less intuition and flying by the seat of one's pants and better positioning for placing prudent bets (securing EV) in the future. The evolving advantage of game theory to social scientists is that game theory draws attention to the range and weighting of human motivations in the course of decision-making more than any previous methodology in the social sciences [31].

When the overly restrictive stipulation of self – interest is set aside as the sole human motivation, rationality can still be preserved and shown to be as robust as in classical modeling [59]. And, in PD cases as illustrated in table 1, access to cell IV with its greater EV for the pair, looms compellingly as the evident choice for all players. When additional motivations, appropriately weighted, are considered along with an appropriately weighted value for self – interest, a once formidable paradox gives way to a decision procedure more sensitive to general welfare benefit. The satisficing of appreciably finite contests can serve aptly for generalizing welfare benefit on increasingly larger scale with ever more generalized descriptions of human nature provided by the social sciences.

Vilfredo Pareto described a special type of normative equilibrium [60]. In Pareto optimality, there is an ideal point such that if anything changed for any player than there would be a decrease in the distribution of optimal benefaction for each and every player [60]. In the PD illustrated in table 1 above, there is an evident Nash equilibrium that is satisficing on von Neumann and Morgenstern's principles. But, the inaccessibility of optimal EV for the pair, evident in the more mutually benefitting, cell IV, makes such an equilibrium seem alarmingly deficient [32].

Securing the optimal EV for the pair and which also secures an optimal EV for each player - seems the way to go. Any decision procedure which fails to point the way to such a solution seems prima facie deeply flawed. So rather than insist on treating every player as self – interested, in situations where the game can be defined in non-zero sum terms (including constant sum games)or in cases of coalition benefit, it is clearly better to seek Pareto optimality or coalition well – being over individual benefit (as suits the specific problem frame and respective information sets)[61].

Seeking Pareto optimality requires abandoning the standard classic assumption of self-interest in light of empirically based psychological studies and subsequent generalizations. More than ever before advances in evolutionary psychology and behavioral economics in particular are revealing much about players expected and hoped for utilities in life [61, 62].

Specifically motivations have been identified that empirical research has shown sometimes trump the constraint of self – interest [63]. This insight was pivotal as the paths subsequently pursued by mathematical game theory and social science merged.

Game theory demonstrated that identifying relevant human motivations is necessary if decision theory is to be increasingly informative both descriptively and prescriptively. In addition, neuroscientists found in these enriched models of cognitive function an apparent supervening upon neurological activity. In addition, game theory made social theorists increasingly aware of the range of actual players and player interests in both intra-cultural and intercultural contexts. Real world concerns with accessing Rousseau's fabled "will of the people" have been invigorated. Renewed attention to lotteries [64] and voting practices has led to revisions of Condorcet's Jury Theorem [65] and the grim realities posed by Arrow's paradox [66]. For anything to count as a science mathematical management of data and mathematical predictions seemed essential [1]

Quality control theorists and operations researchers both were similarly extending the range of their vision from abstract modeling to modeling with real human players in mind. For example, the physicist W. Edward Deming [67] in prescribing holistic approaches to quality control advised senior decision – makers to imagine the sport of crew. Each member of a team of eight and a coxswain may be excellent in her own right. Yet this team of excellent athletes may lose to a team of less talented athletes who had learned to row together more efficiently. Coordination and cooperation were proving to be demonstrably valuable assets in addition to the excellencies of individual participants. Despite the human tendency to want to show off individual excellence mathematical modeling was showing the way to establishing empirical evidence for the fact that cooperation and coordination are necessary to improve EV humans could reasonably come to expect.

Despite rhetoric to the contrary, folk psychology for most of the twentieth century in business and in other practical pursuits still seemed to imagine human competition as did Homer of Greek antiquity. Homer imagined armies fighting in the shadow of their respective heroes Ajax and Achilles. Find the vulnerable heel of the champion and the entire community loses its sense of conviction or so the folk psychology of the time attests. Mathematical modeling and game theory are showing that humans like all other herd species are much more likely to approach equilibrium in cooperative efforts by becoming more rationally astute in aggregating expectations and utilities in a fashion that optimizes EV for all players in the games of life.

A skull crew may have Hercules, Samson and six other super athletes but if each super athlete is violently working hard in his own way, the skull may jerk about in modestly productive thrusts as compared to an eight comprising lesser individual athletes but exhibiting greater team coordination. There is in this example an analogical metaphor with game theory's Pareto optimality. Cooperative play was increasingly becoming evident as a means for extracting the optimal utility from individual effort. From non-zero and cooperative sum games to total quality management and team sports and many PD contexts as well organizational proficiency could be deliberately increased as a result of deliberatively choreographing coalitional activity.

Games are being devised to reveal the potency of preferences such as variances of altruism that support the productive value of ever greater networks of cooperation [24]. Some of these games have become quite famous for revealing non-self-interested preferences in actual decision – making contexts. For example, versions of the Ultimatum Game and the Dictator Game (a conceptual derivative of the Ultimatum Game) demonstrate that people act altruistically at times. Such games have also revealed that there are a variety of different types of altruism ranging from reciprocal altruism to pure altruism [68]. Applications of game theoretic thinking to experimental situations have also shown that money (a supposed veritable token of self-interest under the classical schemes of von Neumann and Morgenstern). For example, one experiment found that able-bodied people were willing to help a stranger move a couch into a house when simply asked. In contrast, seemingly similar individuals would refuse to help if the solicitation involved a monetary reward of less than twenty dollars [68]. An offer of what some regarded as paltry was not only non-motivating but it had a dampening effect on response to requests for help. People seem to have some altruistic preference to help another in need. They also seem to calculate the value of money which increases their range of choices in life, against some value they assign to their labor we may have parochially referred to in the past as personal dignity.

Another startling advance in the social sciences stimulated by applications of game theoretic modeling techniques include the experimentally derived observation that in actual decision-making contexts, preferencing is not always transitive [69]. Imagine a fellow, Jones, whose prioritized preferences in life are ordered as follows: wine (w), women (f) and song (s) and getting close to his creator through prayer (p). So, whenever he is considering the utility of some act or, practice, we have following general order of his preferences as follows:

$$w \geq f \geq s \geq p.$$

Unfortunately, Jones has enjoyed way too much wine over the years. So now, Jones' doctor informs him that regardless of what he does from here on out, Jones will shortly die. The doctor further advises Jones that if he avoids alcohol, he will experience some remission of pain and extend his life somewhat as well. Under such circumstances imagine Jones quits drinking. If preferences are always transitive we should expect Jones will then turn to chasing women more often, singing a bit more and then finally praying a wee bit more as well. The remission of pain and the foregoing of immediate death, afford Jones a chance to enjoy his preferences in life a bit more than his continuing previous behavior would have permitted. So, in light of this consideration Jones eliminates his enjoyment of wine as a preference altogether. His EV for each of the three remaining preferences would increase in ranking under conditions of intransitivity. However, in the real world of sensuously experienced activity it is easy to imagine Jones "turns his life around". Jones may now prefer the activity of prayer above all else. His life may now be driven by dramatically and a transitively revised set of preferences such as:

$$p \geq s \geq f; \ or, \ p \geq f \geq s.$$

Any ordering of the preferences will do to show that with the elimination of a preference it is not at all obvious that rank order of preferences transitively follows. Rather than go through all the permutations it is sufficient simply to show here the plausibility of the transitivity of preferences in actual life situations as problem frames change [70].

Further game theoretic-based experiments are showing the intensity of human motivations in the decision-making process. Concepts such as reputation, disgust and honor are now recognized as central in increasingly apt models of human decision-making. Game theorists have shown that by weighting preferences appropriately prescriptive values including moral commitments can be retained throughout a decision making procedure of nearly any social sort [69].

To illustrate the normatively sustaining points referred to in the paragraph above consider a simple two player zero sum game. Imagine two players. Call them "F" and "E". Both are confined in a prison-like situation and both are starving. A bit of food is given to F. The food is enough for F to survive another day or so but only if he consumes it all himself. E is given nothing. E will surely starve unless F gives him the food. But if F gives E his food then F will starve. This seems like a straight-forward zero sum PD. There is no equilibrium on the face of it. F and E presumably both want to live. The player who has the food should consume it assuming he is rationally self – interested.

This scenario is in fact an actual case as described by Ellie Weisel in his autobiography [71]. F is Ellie's father and E is Ellie himself. Ellie loved his father but he was desperately starving. If his father gave him the food Ellie would survive a day or more. If his father insisted that Ellie take the food and Ellie refused to take the food out of love for his father and the food then sat uneaten, then both would die. With these considerations in mind the game no longer seems so straight – forward. How much should a father's love count in making such a decision? How about the father's sense of honor, reputation or his own disgust at the thought that he might eat his way to his own son's destruction?

Even setting aside these moral preferences there may be other preferences relevant but not strictly moral in and of themselves. Consider time for example. Time is nearly always a factor deserving of some weighted consideration. A pay – off of ten dollars today is likely to be discounted differently than a pay – off of ten dollars ten years from now [50]. Not only is inflation likely to decrease the real dollar value over such a length of time but the recipient's socio-economic status may shift substantially as well. Ten years from now the recipient may have gone from rags to riches and ten dollars isn't a very impressive figure anymore. Moreover in one's new status in life seeking to recover the measly amount of ten dollars may seem a bother or below one's social status. In short, one consideration Father must address is the benefit of strengthening or sustaining the health of himself or his son over time. The caloric expenditure necessary to sustain the father for a day may be sufficient for the son to care for both over two or three days.

An evolutionary theorist may frame this PD by stipulating that it is a constant sum game rather than a zero sum game with father and son both equally committed to passing along their similar genes. In this case many of the moral considerations disappear and are replaced by economic considerations of evolutionary value. If the son's prospects for survival seem better than the father's any paradox fades into an equilibrium achieved in behalf of the survival of the community genes rather than either gene-carrier.

There is little to warrant thinking that sufficient background information can ever be sufficient for sorting through such destabilizing trauma [70]. This does not mean that game theory or other mathematical models of things such as swarm intelligence are of little value [72]. Rather, the point is that the coincidental crossing of paths between science and mathematics gives us increasing and well-earned confidence that we can increasingly manage world events but never to the point that mathematical certainty will account for all the vicissitudes of nature [72]. Supervenient applications of mathematical structures to the world of experience assist in scientifically understanding the world but never to the point of subordinating natural processes to our mathematical modeling [36].

The ambitions of Morgenstern [74] in rendering all human social activity to transparency through game theoretic modeling will never be fulfilled. With each new advance in game theoretic models of human behavior and biology, new understandings of the human social and cognitive dynamic emerges. However, while game theoretic modeling has become an indispensable device both in learning more about human action and normatively by matching more fully human action with human intent, the excavating efforts of such research are unlikely to ever be complete. Human nature and the environment are too complex. And, evolution never lets matters rest as they are.

By accommodating human preferencing and intent, game theoretic developments help humans improve their interactions with the world in more predictable and systematic fashion. Before game theory and modern decision theory, moral values and other social commitments were honored in speech but too often forgotten or over looked by well-meaning decision-makers who forgot these commitments once the seemingly more quantifiable elements of dollars and cents made an easier cost/benefit analysis [75]. Game and decision theory have shown how utilities of any sort can be heuristically quantified to preserve more conscientious decision-making and presumably achieve a better world for all [48,49,58,70].

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