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THEORY OF MOVES: OVERVIEW AND EXAMPLES

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Abstract

The theory of moves is a dynamic theory in which players are permitted to move and countermove in a game, based on nonmyopic calculations. New rules of play are proposed, and a new equilibrium concept is defined, that presume that (1) games have a history; (2) players make "two-sided" rationality calculations; (3) players may consider repetition of the identical game irrational; (4) power asymmetries are possible (in which case repetition may be rational in order to wear down an opponent or establish a reputation); and (5) information may be incomplete.

The calculation of "nonmyopic equilibria" is illustrated in one of the 57 2 x 2 strict ordinal conflict games in which there is no mutually best outcome; these equilibria are given for the other 57 games. Order, moving, and threat power are briefly discussed and their effects noted in the 57 games. The theory is applied to the 1979-80 Iran hostage crisis, in which President Carter misperceived Ayatollah Khomeini's preferences and behaved differently from what classical game theory predicts as the Nash equilibrium.

THEORY OF MOVES: OVERVIEW AND EXAMPLES

"We discussed what the Soviet reaction would be to any possible move by the United States, what our reaction with them would have to be to that Soviet reaction, and so on, trying to follow each of those roads to their ultimate conclusion."

Theodore C. Sorensen about the deliberations of the Executive Committee during the October 1962 Cuban missile crisis (Holsti, Brody, and North, 1964, p. 188).

"What are you going to do after that? Look ahead, look ahead--two or three or four steps ahead."

Mikhail S. Gorbachev to emissaries of the junta that staged the August 1991 attempted coup in the Soviet Union (Clines, 1991).

Introductory Note by Steven J. Brams

A presidential address is, of course, given by the president, which indeed was the case when I addressed the 25th Annual Meeting of the Peace Science Society (International) in Ann Arbor, Michigan, November 15-17, 1991. Such addresses normally give an oldtimer a chance to offer a perspective on, and provide an assessment of, a field of study. In my case, applications of game theory to peace science seemed a natural subject to discuss.

But this address departs from the custom of presidential addresses in two ways. First, I have a coauthor, Walter Mattli, who contributed the valuable material on the Iran hostage crisis at the end. Walter originally developed his analysis for a course I taught in 1986 when he was a graduate student at NYU. Second, our paper is less a critical assessment of applications of game theory to peace science than an argument for reorienting the classical theory itself to make it more applicable to real-world conflict (like the Iran hostage crisis).

While quite lengthy, our paper provides only an outline. I have written a book that goes into considerably more technical detail about the theory and illustrates it with a variety of applications (Brams, 1992). Our main purpose here is to highlight the theory's rationale and explanatory power in peace science.

FEATURES OF THE NEW THEORY

The theory of moves (TOM) brings a dynamic dimension to the classical theory of games, which its founders characterized as "thoroughly static" (von Neumann and Morgenstern, 1944; 3d ed., 1953, p. 44). By postulating that players think ahead not just to the immediate consequences of making moves but also to the consequences of countermoves to these moves, counter-countermoves, and so on, TOM extends strategic thinking into the more distant future. In elucidating the rational flow of moves over time, it facilitates the dynamic analysis of conflicts in which thoughtful and intelligent (but not superintelligent!) players might find themselves engaged. The theory has a number of features worth noting at the outset:

1. Tractability. To keep the analysis tractable, TOM concentrates on two-person games in which each player has only two strategies and can strictly rank the resulting four outcomes from best to worst. There are exactly 78 such "strict ordinal" 2 x 2 games—so called because the players order the outcomes but do not attach cardinal utilities to them—but TOM focuses on the 57 "conflict games" in which there is no mutually best outcome.

The theory is built around three basic concepts:

- "nonmyopic equilibria," or the stable outcomes induced when the players think ahead;
- outcomes induced when one player has "moving power," "order power," or "threat power";

- incomplete information, either about player preferences or the possessor of power in a game.

We will compare nonmyopic equilibria with Nash, or myopic, equilibria, which are the standard equilibria in noncooperative game theory. In addition, we show how the possession of moving, order, or threat power can sometimes upset Nash equilibria—or stabilize nonequilibria—when there is an asymmetry in the capabilities of the two players due to a power imbalance. Finally, we indicate how incomplete information may lead to misperception in certain situations and illustrate its consequences in the Iran hostage crisis.

2. *Applicability.* To build foundations for the theory of moves, we postulate radical changes in the rules of play of classical game theory that, in our opinion, have strong intuitive appeal. These changes are necessary, in our opinion, to explicate and interpret the rational calculations that players make in many real-life situations.

As evidence for this point, we analyze the Iran hostage crisis (1979-81) as a two-person game between President Jimmy Carter and Ayatollah Ruholla Khomeini. Carter, we argue, seriously misperceived Khomeini's preferences and capabilities. This case is invoked not simply to provide a sketchy illustration of the ideas of the theory but rather to depict in some detail how these leaders, as players, arrived at the outcome that they did. We conclude, contrary to some reports on this crisis, that Carter's calculations and actions were rational, given the information he had at the time.

3. Systematic Results. By analyzing *all* possible ordinal configurations in which two players, each with two strategies, may find themselves embedded, we are able to give systematic results, based on only a few rules of play, for all 2 x 2 strict ordinal games. This analysis uncovers a number of subtleties, such as the three nonmyopic equilibria (versus one Nash equilibrium) in the game used to illustrate the analysis later. We will not try to preview other findings of TOM here but instead would stress that the insights the theory offers in strategic situations as simple as 2 x 2 games are often compelling and, by and large, substantiated by other empirical cases (Brams, 1992).

4. A Starting Point. In game theory, a clear demarcation is made between games in "normal form," which are described by payoff matrices, and games in "extensive form," which are described by game trees. Although game trees can often (though not always) be faithfully translated into payoff matrices, the reverse is not the case because strategies hide the sequential choices in a game tree.

With TOM we are less interested in recapturing a particular sequence of choices than in exploring how the *structure* of payoffs in a matrix affects play of a game generally. For this purpose, we start with the payoff matrices of 2 x 2 games and then, because we assume that players think ahead, do game-tree analysis *within* the matrices.

Our unorthodox mixing of the normal and extensive forms has ramifications for the play of a game. Instead of choosing strategies in a payoff matrix, whose selection by both players defines an outcome, we assume that players commence play *at* an outcome in a matrix, from which they then may move or not move. This point of departure gives games a beginning, endowing them with a history that helps to explain subsequent player behavior.

Specifically, players are given a basis for comparing whether their moves and countermoves are (nonmyopically) rational—that is, whether they lead to preferred outcomes that themselves have long-term stability. By contrast, the rationality of player choices is not so apparent when players, according to the classical theory, select strategies *de novo* in matrix games.[1]

5. Future Horizons. Given that a series of moves and countermoves from any starting outcome is possible, it is reasonable to ask *how far* players think ahead in deciding whether or not to move. We assume, initially, that they calculate that if their moves trigger a series of responses that return them to the starting outcome, they will not move in the first place. But we abandon this assumption later and permit cycling, demonstrating how a player with moving power, by being able to force the other player to stop, can break a cycle and, on occasion, induce a better outcome for itself.[2] In the case of threat power, we assume repeated play of a game, which extends still further the future horizon.

6. Building Blocks for Larger Games. Of course, even the systematic analysis of all 2 x 2 games does not reveal all the complexities and nuances that may occur in larger games, with either more strategies, more players, or both. But some of the building blocks we provide can be extended to larger

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[1]If players do begin by choosing strategies, we assume that they can anticipate subsequent moves in the matrix and, on this basis, play an "anticipation game." Also, in defining threat power, we assume that players choose strategies, or threaten their choice, to influence subsequent moves in the matrix game.

[2]To sidestep using either the masculine or feminine gender, or switching back and forth between them in a distracting way, we use the neuter gender for players, except when it is obviously out of place or awkward.

games, though not necessarily in precisely the same form as used here (Brams, 1992, ch. 7).

7. A Point of View. As much as providing details on the dynamic analysis of relatively simple games, TOM offers a unified point of view on the study of strategic interaction. This view is intended as somewhat of an antidote to the sophisticated yet often arcane game-theoretic models that adorn the literature, especially in economics, but which do not paint a broad picture (Fisher, 1989). Although these models sometimes offer important insights into strategic interaction, their canvass is narrow. Worse, many are hopelessly far removed from ever being applicable to real-life situations, either for explanatory or prescriptive purposes.

There are, of course, exceptions to such esoteric flights of fancy and, recently, efforts to make the more striking findings of game theory accessible to a wider audience (e.g., Kreps, 1990; Dixit and Nalebuff, 1991; McMillan, 1992). But there is not, in our opinion, a major alternative theoretical approach that has been developed with an eye to applications.

8. Fruitfulness. TOM is by no means the be-all and end-all of applied game-theoretic modeling. The dynamic analysis of ordinal games still has gaps that need to be filled and details that need to be worked out.

Because TOM is rooted only in ordinal preferences—not cardinal utilities, which are almost always impossible to ascertain in real-life situations—it is relatively easy to understand and simple to apply. At the same time, TOM has considerable richness, allowing for different levels of anticipation, power asymmetries, incomplete information, cycling, and the like.

This richness, as well as its incompleteness and rough edges, augers well, I believe, for TOM's fruitful further development. But we caution that the theory's mathematical extension to larger games should not be mindlessly pursued by making, for example, prodigious nonmyopic calculations on the computer. Ultimately, simplifications and generalizations will be required to make the explosion of results from such an exercise interpretable and applicable to real-life situations. A strategy for extending the theory needs to be well thought out to give the theory breadth, depth, and applicability.

THE CLASSICAL THEORY

Classical game theory, as developed by von Neumann and Morgenstern (1944; 3d ed., 1953), distinguishes between the *extensive form* of a game and the *normal* (or *strategic) form*. The extensive form is represented by a *game tree*, in which the players make sequential choices, knowing some or all the prior choices of the other players. The normal form is represented by a *payoff matrix*, in which players choose strategies, or complete plans that specify what they will do in every *contingency*—that is, for each known choice of all the other players.

TOM makes use of both forms. A payoff matrix defines the *game configuration*, which gives the basic structure of payoffs. An example of such a structure is shown in Figure 1, which we identify as game #56.[3]

Figure 1 about here

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[3]All different game configurations, which we shall say more about shortly, are listed in the Appendix. In TOM, a roman-numeral designation is appended to the game numbers to indicate the initial state at which play starts. Here, however, we shall concentrate on the analysis of configurations, which we identify simply as "games."

Figure I

Game #56

		Column (C)	
		t_1	t_2
Row (R)	s_1	C succeeds (2,4)	R succeeds (4,2) ← Dominant strategy
	s_2	Disaster (1,1)	Compromise (3,3)

Key: (x,y) = (payoff to R, payoff to C)

4 = best; 3 = next best; 2 = next worst; 1 = worst

Nash equilibrium underscored

NMEs circled

Note that Row (R) has two strategies, s_1 and s_2, and Column (C) also has two strategies, t_1 and t_2, making this a 2 x 2 game (i.e., a game in which there are two players, each with two strategies). These strategies may be thought of as alternative courses of action that the players might choose, such as to cooperate or not to cooperate.[4]

The choice of a strategy by R and a strategy by C leads to an outcome, with an associated payoff, at the intersection of these strategies in the payoff matrix. We assume that the players can *strictly* rank the outcomes as follows (i.e., there are no ties): 4 = best; 3 = next best; 2 = next worst; and 1 = worst. Thus, the higher the number, the greater the payoff, but these payoffs are *ordinal*: they indicate only an ordering of outcomes from best to worst, not how much a player prefers one outcome over another.

To illustrate, if a player despises the outcome it ranks 1 but sees little difference among the outcomes it ranks 4, 3, and 2, the "payoff distance" between 4 and 2 will be less than that between 2 and 1, even though the numerical difference between 4 and 2 is greater than that between 2 and 1.[5] Games in which players strictly rank outcomes from best to worst are called *strict ordinal* games.

Assume R chooses s_1 and C chooses t_1 in the Figure 1 payoff matrix. The resulting outcome is that shown in the upper left-hand corner of the

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[4]In more complex games, strategies are plans representing contingent choices. For example, assume C chooses its strategy first. Then a strategy for R might be to choose s_1 if C chose t_1, and to choose s_2 if C chose t_2. As we shall show later, the analysis of such contingent choices is incorporated in TOM via backward induction on game trees.

[5]*How much* a player values an outcome is normally measured in "utilities," but these are not relevant to TOM's predictions, which hold for *any* utilities consistent with player orderings in a game. In the Figure 1 game, for example, assume that the utilities of the players are the same as their ranks: 4, 3, 2, and 1. Now if the two players change their valuations of their worst outcomes from 1 to, say, -100—as the nomenclature of "despise" in the text suggests—the predictions of TOM will be the same.

matrix, with payoffs of (2,4) to the players. By convention, R's payoff is the first number in the ordered pair (2) and C's is the second (4), so R receives its next-worst payoff and C its best payoff. As shorthand verbal descriptions, we call (2,4) "C succeeds," (4,2) "R succeeds," (3,3) "Compromise," and (1,1) "Disaster."

In the next section, we will analyze game #56 using classical game theory. After specifying TOM's rules of play relating to possible moves the players can make, we will then analyze game #56 according to TOM, where we introduce additional rules of play and illustrate the use of "backward induction" by the players in order to look ahead and determine "nonmyopic equilibria." Remarkably, the classical theory shows this game to have only one equilibrium solution, (2,4), whereas TOM demonstrates that (4,2) and (3,3) may also be solutions, depending on where play of the game starts.

Next we illustrate the effects of order, moving, and threat power in game #56. We then apply TOM to the Iran hostage crisis, which illustrates how misperception, resulting from incomplete information, may be incorporated into the analysis. Like game #56, there are multiple nonmyopic equilibria in the game President Carter misperceived that he played against Ayatollah Khomeini. Had Carter correctly perceived Khomeini's preferences, he would have known that the "real game" had only one nonmyopic equilibrium, rendering his threats in this game futile. According to TOM, the best that Carter could have done was let the crisis settle on this equilibrium, which is eventually what he was forced to do.

We conclude with some observations about TOM and the art and science of modeling conflict processes. We also indicate how TOM could be used for normative purposes.

APPLYING THE CLASSICAL THEORY

The classical theory we illustrate in this section is that of the normal form, in which players are assumed to make simultaneous strategy choices in a 2 x 2 game. (If their choices are not literally simultaneous, the normal form assumes them to be independent of each other, so neither R nor C knows each other's choices when it must make its own.) In the next section we will introduce the extensive form and show how it can be applied to the analysis of game #56, based on new rules of play.

First consider what strategy it is rational for R to choose in game #56. If C selects t_1, R has a choice between (2,4) and (1,1) in the first column; its payoff will be 2 if it chooses s_1 and 1 if it chooses s_2. On the other hand, if C chooses t_2, R has a choice between (4,2) and (3,3) in the second column; its payoff will be 4 if it chooses s_1 and 3 if it chooses s_2.

Clearly, R is better off choosing s_1 whatever contingency arises—that is whichever strategy C chooses (t_1 or t_2). When one strategy of a player is unconditionally better than another strategy because its superiority does not depend on the contingency, this strategy is said to be *dominant*. R's strategy of s_1 is dominant, whereas its strategy of s_2 is *dominated*, or unconditionally worse than s_1, because it always leads to inferior payoffs.

C, by contrast, does not have a dominant strategy in game #56. Its better strategy depends on R's strategy choice: if R chooses s_1, C is better off choosing t_1 because it prefers (2,4) to (4,2) in the first row; but if R chooses s_2, C is better off choosing t_2 because it prefers (3,3) to (1,1) in the second row. The fact that C does not have an unconditionally better strategy, independent of the contingency (i.e., R's choice), makes its two strategies *undominated*.

In a game of *complete information*, in which both players have full knowledge of each other's payoffs as well as their own, C will know that R's dominant strategy is s_1. Because s_1 is always better than s_2 for R, C can surmise that R will choose s_1. Given that R chooses s_1, it is rational for C to choose t_1, yielding (2,4) as the rational outcome of the game.

Curiously, this outcome is only R's next-worst (2), though R is the player with the dominant strategy. C, the player without a dominant strategy, obtains its best outcome (4).

Nevertheless, (2,4) has a strong claim to be called *the* solution of game #56. Not only is it the product of one player's (R's) dominant strategy and the other player's best response to this dominant choice, but it is also the unique "Nash equilibrium."

A *Nash equilibrium* (Nash, 1951) is an outcome from which neither player will unilaterally depart because it would do worse, or at least not better, if it did.[6] Thus, if R chooses s_1 and C chooses t_1, giving (2,4), R will not switch to s_2 because it would do worse at (1,1); and C will not switch to t_2 because it would do worse at (4,2). Hence, (2,4) is stable in the sense that, once chosen, neither player would have an incentive to switch by itself to a different strategy.

This is not true in the case of the other three outcomes in game #56. From (4,2), C can do better by departing to (2,4); from (3,3), R can do better

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[6]Technically, this equilibrium is defined by the strategies (s_1 and t_1) that yield this outcome—not the outcome itself—which are "pure" in the sense that they are chosen with certainty. Strategies may also be "mixed," which means that a player chooses a strategy at random according to some probability distribution. Although Nash equilibria may be in mixed strategies, such equilibria are not defined in games with ordinal payoffs. Moreover, even if the ordinal payoffs of game #56 were assumed to be cardinal utilities, this game would not possess a mixed-strategy Nash equilibrium. However, there are 2 x 2 strict ordinal games whose cardinal equivalents do possess mixed-strategy equilibria, which are discussed and compared with the predictions of TOM in Brams (1992).

by departing to (4,2); and from (1,1), either player can do better by departing, R to (2,4) or C to (3,3).

In the latter case, if *both* players switched their strategies—perhaps unbeknownst to the other—in an effort to scramble away from the mutually worst outcome of (1,1), they would end up at (4,2), which also is better for both. Indeed, because (4,2) is R's best outcome, R would be the player that would most welcome a double departure; next most welcome a departure by C alone to (3,3); and least welcome a departure by itself alone to (2,4).

Although C would not particularly welcome a double departure, like R it would prefer that its adversary make the first move from (1,1), because R's departure would yield (2,4), whereas C's departure would yield (3,3). We shall give examples later in which the opposite is true: each player would prefer to be the *first* to depart from an outcome, not wait for its adversary to make the first move.

The classical theory, by assuming that players choose strategies simultaneously, does not raise questions about the rationality of moving or departing from outcomes—at least beyond an immediate departure, à la Nash. In fact, however, most real-life games do not start *with* simultaneous strategy choices but commence *at* outcomes. The question then becomes whether a player, by departing from an outcome, can do better not just in an immediate or myopic sense but, rather, in an extended or nonmyopic sense.

There are 78 2 x 2 strict ordinal games that are structurally distinct in the sense that no interchange of the players, their strategies, or any combination of these can transform one of these games into any other.[7]

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[7]For complete listings of the 78 games, see Rapoport and Guyer (1966) and Brams (1977); for a partial listing that excludes the 21 games with a mutually best (4,4) state, see Brams (1983, pp. 173-177). A listing of the latter games is given in the Appendix.

These games represent *all* the different configurations of ordinal payoffs in which two players, each with two strategies, may find themselves embedded.

Game #56 is only one such configuration. The rules of play we shall propose next apply to all 78 games—and, more generally, to all finite two-person games—but here we shall illustrate them in detail only for game #56. Results for this game provide a preview of some but by no means all the results for the set of 2 x 2 strict ordinal games.

RULES OF PLAY OF TOM

A *game* "is the totality of rules of play which describe it" (von Neumann and Morgenstern, 1953, p. 49).[8] The first four rules of play of TOM for two-person games are as follows:

1. Play starts at an outcome, called the *initial state*, which is at the intersection of the row and column of a payoff matrix.
2. Either player can unilaterally switch its strategy, and thereby change the initial state into a subsequent state, in the same row or column as the initial state.[9] Call the player who switches player 1 (P1).
3. Player 2 (P2) can respond by unilaterally switching its strategy,

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[8]Equating a game with its rules leaves out a lot about how the play of a game gets translated into an outcome. We shall have more to say about this question when we discuss the implications of different sets of rules for the choice of outcomes. Useful explorations of the relationship between games and their rules can be found in Hirshleifer (1985) and Gardner and Ostrom (1990).

[9]We do not use "strategy" in the usual sense to mean a complete plan of responses by the players to all possible contingencies allowed by rules 2–4, because this would make the normal form unduly complicated to analyze. Rather, *strategies* refer to the choices of players that define a state, and *moves and countermoves* to their subsequent strategy switches from an initial state to a final state in an extensive-form game, as allowed by rules 2–4. For another approach to combining the normal and extensive forms, see Mailath, Samuelson, and Swinkels (1991).

thereby moving the game to a new state.

4. The alternating responses continue until the player (P1 or P2) whose turn it is to move next chooses not to switch its strategy. When this happens, the game terminates in a *final state*, which is the *outcome* of the game.

Note that the sequence of moves and countermoves is *strictly alternating* (the possibility of backtracking will be considered later): first, say, R moves, then C moves, and so on, until one player stops, at which point the state reached is final and, therefore, the outcome of the game.

The use of the word "state" is meant to convey the temporary nature of an outcome, before players decide to stop switching strategies. We assume that no payoffs accrue to players from being in a state unless it is the final state and, therefore, becomes the outcome (which could be the initial state if the players choose not to move from it).

Rule 1 differs radically from the rule of play of a normal-form game, in which players simultaneously choose strategies that determine an outcome. Instead of starting from scratch with strategy choices, we assume that players are already *in* some state at the start of play and receive payoffs from this state if they stay. Based on these payoffs, they must decide, individually, whether to change this state in order to try to do better.

To be sure, some decisions are made collectively by players, in which case it would be reasonable to say that they choose strategies simultaneously, or coordinate their choices. But if, say, two countries are coordinating their choices, as when they agree to sign a treaty, the important issue is what individualistic calculations led them up to this point.[10] The formality of jointly signing the treaty covers up the move-countermove process that preceded it. This is precisely what TOM is designed to uncover.

To continue this example, the parties who sign the treaty were in some prior state, from which both desired to move—or, perhaps, only one desired to move and the other could not prevent this move without hurting itself. Eventually they arrive at a new state (e.g., after treaty negotiations) in which it is rational for both countries to sign the treaty that has been negotiated.

Put another way, almost all outcomes of games that we observe have a history. *Our interest is in explaining strategically the progression of (temporary) states that lead to a (more permanent) outcome.* Of course, what is "temporary" and what is "more permanent" depends on one's time frame.

We use the phrase "more permanent," rather than simply "permanent," to underscore the obvious point that nothing in the world is permanent. Less obvious, a state that persists for a week, say, in a crisis may be permanent enough to represent an outcome in the analysis of crisis behavior, whereas a week for most historians is not long enough to qualify as even a state (unless it is exceedingly eventful and gives payoffs to the players for being there).

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[10]By focusing on the calculations of individual players, we eschew the "cooperative" viewpoint in game theory, which assumes that players can make an agreement that is binding and enforceable. If this is the case, they need only be concerned with how to divide up the surplus, accruing from their cooperation, in some equitable or otherwise reasonable manner. But their decision to cooperate in the first place, in our view, should emerge as the result of "noncooperative" individualistic calculations, which would inform them, for example, that such an agreement is stable instead of just assuming this to be the case. Building cooperative game theory on noncooperative foundations is what is known as the "Nash program." It is a program that we endorse and consider to be consistent with the purposes of TOM, which simply offers a different *basis* for making the individualistic calculations of noncooperative game theory.

However defined empirically, we start play of a game *in a state*, at which players accrue payoffs only if they remain in that state so that it becomes the outcome of the game. If they do not remain, they still know what payoffs they *would have accrued* had they stayed and so can make a rational calculation of the advantages of staying or moving. They move precisely because they calculate that they could do better by switching states, anticipating a better outcome when the move-countermove process finally comes to rest.[11]

Thus, we assume that most games have a history, which starts at some initial state. The game is different when play starts elsewhere, and so are the calculations of its players, who occupy different positions (Güth, 1991; Mertens, 1991). The choice of this state, and what constitute future states and eventually an outcome, depends on what the analyst seeks to explain. The time perspective of most political scientists probably ranges between about a week (e.g., in analyzing a crisis) and a generation; journalists are more likely to think in terms of hours and days, whereas the span of most historians varies from a few years to a century or two.

APPLYING TOM

Rules 1–4 say nothing about what *causes* a game to end but only when: termination occurs when a "player whose turn it is to move next chooses not to switch its strategy" (rule 4). But when is it rational not to continue moving, or not to move from the initial state at the start? To answer this question, we posit a rule of *rational termination* (Brams, 1983, pp. 106-107), which has also been called "inertia" (Kilgour and Zagare, 1987, p. 94). It

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[11]We assume that their *mental* calculations of advantage and disadvantage precede, and therefore serve as the basis of, their actual *physical* moves.

prohibits a player from moving from an initial state unless it leads to a *better* (not just the same) final state:

5. A player will not move from an initial state if this move (i) leads to a less preferred final state (i.e., outcome); or if it (ii) returns play to the initial state (i.e., makes the initial state the outcome).

We shall shortly discuss shortly how rational players, starting from some initial state, determine what the outcome will be by using backward induction.

Condition (i) of rule 5 precludes moves to inferior states, and condition (ii) to the same state because of cycling back to the initial state. The latter condition is worth some elaboration. It says that if it is rational, after P1 moves, for play of the game to cycle back to the initial state, P1 will not move in the first place. After all, what is the point of initiating the move-countermove process if play simply returns to "square one," given that the players receive no payoffs along the way (i.e., before an outcome is reached)?

Not only is there no gain from cycling, but in fact there may be a loss because of so-called transaction costs that players suffer when they simply repeat themselves. Therefore, it seems sensible to assume that players will not trigger a move-countermove process if they will only return to the initial state, making it the outcome.

At this point, however, we make rule 5 only provisional; an alternative rule (5') that allows for cycling will be considered later (along with "moving power" as a way to break cycles). We call rules 5 and 5' *rationality rules*, because they provide the basis for players to determine whether they can do better by moving from or staying in some state.

A final rule of TOM is needed to ensure that *both* players take into account each other's calculations before deciding to move from the initial state. We call this rule the *two-sidedness rule*:

6. Players have complete information about each other's preferences and the rules of TOM. They take into account the consequences of the other player's rational choices, as well as their own, in deciding whether to move from the initial state or subsequently, based on backward induction. If it is rational for one player to move and the other player not to move from the initial state, then the outcome will be that induced by the player who moves.

Later we will relax the assumption of complete information to take account not only of incomplete information but also the possibility of misperception by the players.

Because players have complete information, they can look ahead and anticipate the consequences of their moves. To see how they do so and illustrate the meaning of *backward induction*, consider again game #56. We show below the progression of moves, starting from each of the four possible initial states and cycling back to this state, and indicate where rational players will terminate play:[12]

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[12]Where, of course, depends on the endpoint, or *anchor*, from which the backward induction proceeds, which we assume here—for reasons given in the text—is after one complete cycle. This assumption defines a finite extensive-form game, to which most of the so-called refinements of Nash equilibria, including subgame perfection, are applicable. However, the assumption of an anchor is dropped later, where the alternative rationality rule is applied to "cyclic games," which are not finite because they may cycle indefinitely. They are used to define "moving power" and become finite only when the player with moving power dictates where play terminates. Because when this occurs is not specified, only where (i.e., the state), a finite extensive-form game is not defined. Consequently, the Nash refinements, which are discussed in several recent game theory texts (Rasmusen, 1989; Friedman, 1990; Myerson, 1991; Fudenberg and Kreps, 1991; Binmore, 1992), are not in general applicable to TOM. By contrast, Skyrms (1990)

1. Initial state (2,4). If R moves first, the counterclockwise progression from (2,4) back to (2,4)—with the player (R or C) who makes the next move shown above each state in the alternating sequence—is as follows (see Figure 1):

	R		C		R		C		
R starts:	(2,4)	→	(1,1)	→	<u>(3,3)</u>	→|	(4,2)	→	(2,4)
Survivor:	(3,3)		(3,3)		(3,3)		(2,4)		

The survivor is determined by working backwards. Assume the players' alternating moves have taken them counterclockwise from (2,4) to (1,1) to (3,3) to (4,2), at which point C must decide whether to stop at (4,2) or complete the cycle and return to (2,4). Clearly, C prefers (2,4) to (4,2), so (2,4) is listed as the survivor below (4,2): because C *would* move the process back to (2,4) once it reached (4,2), the players would know that if the move-countermove process reached (4,2), the outcome would be (2,4).

Knowing this, would R at the prior state, (3,3), move to (4,2)? Because R prefers (3,3) to the survivor at (4,2)—namely, (2,4)—the answer is "no." Hence, (3,3) becomes the survivor when R must choose between stopping at (3,3) or moving to (4,2)—which, as we have just shown, would become (2,4).

At the prior state, (1,1), C would prefer moving to (3,3) than stopping at (1,1), so (3,3) again is the survivor if the process reaches (1,1). Similarly, at the initial state, (2,4), because R prefers the previous survivor, (3,3), to (2,4), (3,3) is the survivor at this state as well.

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analyzes these refinements, using a dynamic model that assumes players maximize expected utility and do Bayesian updating. Whereas TOM is nonmyopic and nonquantitative, postulating only ordinal payoffs and discrete moves between states, Skyrms' model is myopic and quantitative, postulating cardinal payoffs and continuous moves.

The fact that (3,3) is the survivor at initial state (2,4) means that it is rational for R initially to move to (1,1), and C subsequently to move to (3,3), where the process will stop, making (3,3) the rational choice if R has the opportunity to move first from initial state (2,4). That is, after working *backward* from C's choice of completing the cycle or not at (4,2), the players can reverse the process and, looking *forward*, determine that it is rational for R to move from (2,4) to (1,1), C to move from (1,1) to (3,3), at which point R will stop the move-countermove process at (3,3).

Notice that R does better at (3,3) than (2,4), where it could have terminated play, and C does better at (3,3) than (1,1), where it could have terminated play, given R is the first to move. We indicate that (3,3) is the consequence of backward induction by underscoring this state in the progression; it is the place at which *stoppage* of the process occurs. In addition, we indicate that it not rational for R to move on from (3,3) by the vertical line blocking the arrow emanating from (3,3), which we refer to as *blockage*: a player will always stop at a blocked state, wherever it is in the progression. Stoppage occurs when blockage occurs for the *first* time, as we illustrate next.

If C is the player who can move first from (2,4), backward induction shows that (2,4) is the last survivor, so (2,4) is underscored when C starts. Consequently, C would *not* move from the initial state, where there is blockage (and stoppage), which is hardly surprising since C receives its best payoff in this state:[13]

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[13]But it is rational in several 2 x 2 games for a player to be "magnanimous" and depart from its best state 4, because in these games it would do worse if the other player departed first (Brams, 1992; Brams and Mor, forthcoming).

	C		R		C		R		
C starts:	<u>(2,4)</u>	→|	(4,2)	→|	(3,3)	→	(1,1)	→	(2,4)
Survivor:	(2,4)		(4,2)		(2,4)		(2,4)		

As when R has the first move, (2,4) is the first survivor, working backward from the end of the progression. But then, because R at (4,2) prefers (4,2) to (2,4), (2,4) is temporarily displaced as the survivor. It returns as the last survivor, however, because C at (2,4) prefers (2,4) to (4,2).

Thus, the first blockage and, therefore, stoppage occurs at (2,4), but blockage occurs subsequently at (4,2) should, for any reason, stoppage not terminate moves at the start. In other words, if C moved initially, R would then be blocked at (4,2). Hence, blockage occurs at two states when C starts the move-countermove process, whereas it occurs only once when R has the first move.

The fact that the rational choice depends on which player has the first move—(3,3) is rational if R starts, (2,4) if C starts—leads to a conflict over what outcome will be selected, starting at (2,4). However, because it is not rational for C to move from the initial state, R's move takes precedence, according to rule 6, and overrides C's decision to stay. Consequently, when the initial state is (2,4), the result will be

Outcome: (3,3).

2. *Initial state (4,2).* The progressions, survivors, stoppages, blockages, and outcome from this state are as follows:

	R		C		R		C		
R starts:	<u>(4,2)</u>	→|	(3,3)	→	(1,1)	→	(2,4)	→|	(4,2)
Survivor:	(4,2)		(2,4)		(2,4)		(2,4)		

<table>
<tr><td></td><td>C</td><td></td><td>R</td><td></td><td>C</td><td></td><td>R</td><td></td><td></td></tr>
<tr><td>C starts:</td><td>(4,2)</td><td>→|c</td><td>(2,4)</td><td>→</td><td>(1,1)</td><td>→</td><td>(3,3)</td><td>→</td><td>(4,2)</td></tr>
<tr><td>Survivor:</td><td>(4,2)</td><td></td><td>(4,2)</td><td></td><td>(4,2)</td><td></td><td>(4,2)</td><td></td><td></td></tr>
</table>

Outcome: (4,2)

There is obviously no conflict when (4,2) is the initial state. Yet while neither player has an incentive to move from (4,2), the reasons of each player for stoppage are different. If R starts, there is blockage at the start, whereas if C starts, there will be cycling back to (4,2). But because cycling is no better for C than not moving, C will stay at (4,2) according to rule 5, which I indicate by "c" (for cycling) following the arrow at (4,2). (This might be interpreted as a special form of blockage.) Thus, (4,2) is the consensus choice as the outcome.

3. *Initial state (3,3).* The progressions, survivors, stoppages, blockages, and outcome from this state are as follows:

<table>
<tr><td></td><td>R</td><td></td><td>C</td><td></td><td>R</td><td></td><td>C</td><td></td><td></td></tr>
<tr><td>R starts:</td><td>(3,3)</td><td>→| c</td><td>(4,2)</td><td>→</td><td>(2,4)</td><td>→</td><td>(1,1)</td><td>→</td><td>(3,3)</td></tr>
<tr><td>Survivor:</td><td>(3,3)</td><td></td><td>(3,3)</td><td></td><td>(3,3)</td><td></td><td>(3,3)</td><td></td><td></td></tr>
</table>

<table>
<tr><td></td><td>C</td><td></td><td>R</td><td></td><td>C</td><td></td><td>R</td><td></td><td></td></tr>
<tr><td>C starts:</td><td>(3,3)</td><td>→</td><td>(1,1)</td><td>→</td><td>(2,4)</td><td>→|</td><td>(4,2)</td><td>→|</td><td>(3,3)</td></tr>
<tr><td>Survivor:</td><td>(2,4)</td><td></td><td>(2,4)</td><td></td><td>(2,4)</td><td></td><td>(4,2)</td><td></td><td></td></tr>
</table>

Outcome: (2,4)

As from initial state (2,4), there is a conflict. If R starts, (3,3) is the rational choice, but if C starts (2,4) is. But because C's move takes precedence over R's staying, the outcome is that which C can induce—namely, (2,4).

4. Initial state (1,1). The progressions, survivors, stoppages, blockages, and outcome from this state are as follows:

<table>
<tr><td></td><td>R</td><td></td><td>C</td><td></td><td>R</td><td></td><td>C</td><td></td><td></td></tr>
<tr><td>R starts:</td><td>(1,1)</td><td>→</td><td>(2,4)</td><td>→|</td><td>(4,2)</td><td>→|</td><td>(3,3)</td><td>→|</td><td>(1,1)</td></tr>
<tr><td>Survivor:</td><td>(2,4)</td><td></td><td>(2,4)</td><td></td><td>(4,2)</td><td></td><td>(3,3)</td><td></td><td></td></tr>
</table>

<table>
<tr><td></td><td>C</td><td></td><td>R</td><td></td><td>C</td><td></td><td>R</td><td></td><td></td></tr>
<tr><td>C starts:</td><td>(1,1)</td><td>→</td><td>(3,3)</td><td>→|</td><td>(4,2)</td><td>→</td><td>(2,4)</td><td>→|</td><td>(1,1)</td></tr>
<tr><td>Survivor:</td><td>(3,3)</td><td></td><td>(3,3)</td><td></td><td>(2,4)</td><td></td><td>(2,4)</td><td></td><td></td></tr>
</table>

Outcome: Indeterminate—(2,4)/(3,3), depending on whether R/C starts.

Unlike the conflicts from initial states (2,4) and (3,3), it is rational for *both* players to move from initial state (1,1). But, strangely enough, each player would prefer that the other player be P1, because

- R's initial move induces (2,4), C's preferred outcome; and
- C's initial move induces (3,3), R's preferred outcome.

Presumably, each player will try to hold out longer at (1,1), hoping that the other player will move first. Because neither player's move takes precedence according to the rules of play (later we shall show how "order power" establishes precedence), neither rational choice can be singled out as the outcome. Hence, we classify the outcome, when play starts at (1,1), as *indeterminate*—either (2,4) or (3,3) may occur, depending on which player P1 is. Because the choice of first mover is not specified exogeneously in this situation (i.e., by the rules of play), indeterminacy emerges endogeneously—it is a consequence of TOM.

Typically, this kind of indeterminacy characterizes bargaining (Brams, 1990), wherein each player tries to hold off being the first to make concessions. Although both players would benefit at either (2,4) or (3,3) over (1,1), there is greater benefit to letting the other player move first. Note, however, that the state which R most prefers, (4,2), is unattainable from (1,1)—it can occur only if the process starts at (4,2).

To summarize, each of the initial states goes into the following final states, or outcomes:

$$(2,4) \rightarrow (3,3); \quad (4,2) \rightarrow (4,2); \quad (3,3) \rightarrow (2,4); \quad (1,1) \rightarrow (2,4)/(3,3).$$

We call the outcomes into which each state goes *nonmyopic equilibria* (NMEs), because they are the consequence of both players' looking ahead and making rational calculations of where, from each of the initial states, the move-countermove process will end up.

In game #56, there are three different NMEs, which is the maximum number that can occur in a strict ordinal 2 x 2 game; the minimum is one.[14]

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[14]That every 2 x 2 game contains at least one NME follows from the fact that, from each initial state, there is an outcome (perhaps indeterminate) of the move-countermove process. If this outcome is both determinate and the same from every initial state, then it is the only NME; otherwise, there is more than one NME. There was no such existence result in the original theory of moves—as first developed in Brams and Wittman (1981) and then extended in a series of articles that are summarized in Brams (1983)—in which the move-countermove process was assumed to terminate only if the player with the next move reached a state that gave it its best payoff (4). Because this point is never reached in 41 of the 78 2 x 2 strict ordinal games, no predictions of stable outcomes could be made for the majority of the 78 games, based on the original theory. On the other hand, a weaker equilibrium concept, called an "absorbing outcome," was proposed by Brams and Hessel (1982) for these 41 games, but it, like a nonmyopic equilibrium in the original theory, is ad hoc and also not consistent with some of the original nonmyopic equilibria in the 37 games that possess them. Extensions of nonmyopic equilibria have been proposed in Kilgour (1984, 1985) and Zagare (1984). Marschak and Selten (1978) and

Most 2 x 2 games have either one or two NMEs, as shown in the Appendix, wherein games are classified according to the number of their NMEs. The point we wish to emphasize here is that *where* play starts in a game can matter, which the unique (2,4) Nash equilibrium in game #56, based on the classical theory, masks.

ORDER, MOVING, AND THREAT POWER

Power is probably the most suggestive concept in the vocabulary of political scientists. It is also one of the most intractable, bristling with apparently different meanings and implications.

In this section I illustrate three different kinds of power in game #56, all of which introduce an asymmetry into play of a game. The simplest concept is "order power," which is defined only for games with indeterminate states. As noted in the previous section, (1,1) is such a state in game #56, because when play starts at this state, the outcome may be either (2,4) or (3,3), depending of whether R or C moves first from this state.

A player has *order power* when it can dictate the order of moves from an indeterminate initial state and thereby ensure a preferred outcome for itself. Thus, if R has order power when play commences at (1,1), it can force C to move first to (3,3), which, based on backward induction, is where play would stop (as shown earlier). By the same token, if C has order power, it can force R to move first to (2,4), illustrating how each player can benefit by being able to force the other player to move first from (1,1).

In some games, a player benefits by moving first, not second, from an indeterminate state (i.e., being P1 rather than P2). In either event, order power is applicable only when the initial state is *Pareto-inferior* (i.e., worse

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Hirshleifer (1985) have investigated related equilibrium concepts, based on different rules of play.

for both players than some other state), so both players desire to move from it. However, because the NME into which the state goes depends on which player moves first from it, and the players prefer different NMEs, each benefits from being able to determine the order of moves.

We show this ability of the players in the *anticipation game* (AG) of game #56 in Figure 2, which depicts the NMEs into which each state of

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Figure 2 about here

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the original game goes. Thus, below (1,1) we show in brackets [2,4]/[3,3], which indicates that if R moves first from (1,1), the NME will be [2,4], whereas if C moves first the NME will be [3,3]. Similarly, below the other states, which are all determinate, we depict the (single) NMEs into which each state goes.

Suppose that the players, contrary to rule 1 of TOM, do not start at some initial state. Rather, they choose *strategies* in AG in order to select a state, which they can anticipate, based on TOM, will go into a particular outcome (perhaps indeterminate, as in game #56).

If players choose strategies in AG rather than start from states in the original game, then one can apply the classical theory to AG. Thus, in the AG of game #56 R has a dominant strategy of s_1: whether C chooses t_1 or t_2, R receives at least as high and sometimes a higher payoff by choosing s_1. Given that C believes R will choose its dominant strategy, C, preferring [3,3] to [4,2], will choose t_1 in the AG.

In fact, [3,3] is the unique Nash equilibrium in the AG of game #56. Hence, if an initial state is not given (as TOM assumes), but instead the players (i) choose strategies that induce it and (ii) can anticipate the NME that that state will go into, (3,3) is the NME that they will select.

Figure 2

Game #56 and Its Anticipation Game (AG)

Column (C)

		t_1		t_2	
	s_1	(2,4) [3,3]	←	(4,2) [4,2]	← Dominant strategy
Row (R)		↓		↑	
	s_2	(1,1) [2,4]/[3,3]	→	(3,3) [2,4]	

Key: (x,y) = (payoff to R, payoff to C)

[x,y] = [payoff to R, payoff to C] in anticipation game (AG)

4 = best; 3 = next best; 2 = next worst; 1 = worst

Nash equilibria in original game and AG underscored

NMEs circled

Arrows indicate direction of cycling

Order power differs from from two related concepts, "staying power" (Brams, 1983; Brams and Hessel, 1983; Kilgour, De, and Hipel, 1987) and "holding power" (Kilgour and Zagare, 1987), in games that are played according to the rules of TOM. The former concept presumes that the possessor always moves second, whereas the latter concept presumes that the possessor moves first but can hold or pass, which allows for the possibility of backtracking by the possessor.[15]

Order power is more general than these other concepts by not specifying the order of play: at the initial state, the possessor can choose to move either first or second. One consequence of this greater freedom is that its possessor never suffers as the power holder, whereas the possessor of both staying power and holding power does worse in certain games than were the other player the possessor of this power.

In our opinion, such reversals are bizarre, casting doubt on the usefulness of staying and holding power as concepts that explain why players, because of their special prerogatives, prevail in situations of conflict. If a prerogative may be a liability, degrading the ability of a player to induce the outcomes it prefers, it seems contradictory to call it "power."

Because a player in an indeterminate state always benefits from its possession of order power, this power is invariably *effective*: it helps the player who possesses it, ensuring it of a better outcome that if the other player had it. By comparison, the concepts of power we shall illustrate

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[15]Admittedly, players may make mistakes and decide to backtrack. While backtracking is not permitted by the rules of TOM in games of complete information, which assumes that players can think ahead and thereby avoid mistakes, TOM can be modified to allow for incomplete information, as we show later. Just as incomplete information may cause players to make mistakes, it also may lead them, once they realize their mistakes, to reassess their positions and decide to backtrack. In this sense, TOM allows for backtracking in games of incomplete information.

next—moving power and threat power—can never hurt a player, but they are not effective in all games.

Moving power singles out certain NMEs, making them the rational choice of the players *independent of the initial state*. The definition of "moving power," however, requires a change in rule 5, which prohibits cycling. Recall that its rationale was that if play returns to the initial state, the players are in the same position as when they started, so why should they move initially?

Yet we know that players may revisit the past again and again, as the six Arab-Israeli wars have shown (Brams and Mor, forthcoming; Brams, 1992). To take account of such conflicts, we postulate a revised rule 5:

> 5'. A player will not move from an initial state if this move leads to a less preferred final state (i.e., outcome). But P1 will move—even if play returns to the initial state and repeatedly cycles—if it (i) has "moving power" and, with it, (ii) can induce a better outcome for itself.

We shall define "moving power" shortly. As for the other rules, we assume that rules 1–4 and rule 6 continue to apply.

By substituting rule 5' for rule 5, we eliminate the prohibition against cycling in TOM and assume, instead, that if one player (Pl) moves from an initial state, and four moves later the other player (P2) completes the cycle in a 2 x 2 game, this is *not* a bar to Pl's moving again from the initial state, even though the players are back to "square one." Indeed, the definition of "moving power" requires repeated cycling:

Pl has *moving power* if it can induce P2 eventually to stop, in the

> process of cycling, at one of the two states at which P2 has the next move—presumably, the state that P2 prefers.[16]

Thus, instead of using backward induction to terminate play, which requires the anchor of the initial state (to which we assume play does not return), we now use one player's superiority to force termination.

To illustrate the implications of rule 5', consider again game #56 in Figure 2. Although a move by R from (1,1) to (2,4) gives C its best payoff and makes it irrational for C to move in a clockwise direction, moves in a counterclockwise direction *never give a player its best payoff when it has the next move*: C at (1,1), R at (3,3), C at (4,2), and R at (2,4) never receive payoffs of 4. When this condition obtains, either in a clockwise or a counterclockwise direction—it cannot hold in both directions in a 2 x 2 game (Brams, 1992)—we call the game *cyclic*.

Game #56 is a cyclic game, with the direction of cycling counterclockwise, as shown by the arrows in Figure 2. If R possesses moving power, it can induce C to stop at either (1,1) or (4,2), where C has the next move. Clearly, R would prefer (4,2), which gives R its most-preferred NME and best payoff, independent of the initial state.

Now assume that C possesses moving power. It can induce R to stop at either (2,4) or (3,3), where R has the next move. R would prefer (3,3),

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[16]An earlier version of this concept was proposed in Brams (1982, 1983). Cycling is allowed but not assumed always to occur (as here) in De, Hipel, and Kilgour (1990), who propose a notion of "hierarchical power." Langlois (1992) permits cycling within a cardinal framework, rooted in expected-utility calculations; because cycling is assumed to be costly, however, both players will eventually want to desist. We do not make that assumption here but instead assume that the player with moving power is essentially indefatigable—at least compared with the player without moving power, who must eventually stop moving. We also assume that only one player can possess moving power at any one time; otherwise, each player could force the other to terminate play at the same time—perhaps out of mutual exhaustion—which would indicate the *lack* of a power asymmetry.

where it obtains its next-best payoff,[17] which makes moving power effective: each player induces a better NME—(4,2) for R and (3,3) for C—when it possesses moving power than when its opponent does.

But in other cyclic games it makes no difference which player possesses moving power—the outcome induced is the same. In these games, moving power is ineffective, which will be illustrated in the case of one game modeling the Iran hostage crisis.

When moving power in a cyclic game is effective, a player may try to indicate at the start of play that it is willing and able to cycle indefinitely to assert its moving power. It may do this by continuing to move if an opponent does, thereby signaling that it "means business." But this display of resoluteness does not mean that it will in fact be able to outlast its opponent in repeated cycling, because which player has moving power may not be *common knowledge* (i.e., known to both players, with each knowing that the other knows, knowing that the other knows that each knows, and so on *ad infinitum*).

It is not always evident in a situation whether the players would prefer to end their conflict before cycling, which is the assumption of rule 5, or to cycle, which rule 5' permits. If the possessor of moving power has not yet been established, and moving power is effective, cycling will certainly be advantageous for the player who does have this power.

If who will ultimately prevail *is* known under rule 5', mental moves can presumably substitute for physical moves—in a kind of thought experiment of the players—obviating the need for a test of strength by means of cycling.

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[17]Although R obtains its payoff at (4,2), it cannot induce this NME with its moving power.

Indeed, the reputations of the players may have a lot to do whether they actually cycle.

Reputations will also affect the credibility of any threats the players may make. But threat power, unlike moving power, is not based on the ability of one player to continue moving indefinitely in a cyclic game (Brams, 1983, 1990; Brams and Hessel, 1984). Instead, threat power assumes that one player can threaten the other with the possibility of a Pareto-inferior state—by communicating its intentions in advance—to induce a *Pareto-superior* state (i.e., one better for both players than the Pareto-inferior state).

In game #56, for example, C, by saying it will choose its first strategy, gives R a choice between (2,4) and (1,1). Obviously, R prefers the Pareto-superior (2,4) to the Pareto-inferior (1,1) and would, presumably, choose its first strategy if it thought that C, with threat power, could hold out longer at (1,1). Thereby, C compels the choice of (2,4), and, following Schelling (1966), we call such a threat *compellent*. (The other kind of threat we shall discuss, "deterrent," will be illustrated in the case of one of the games used to model the Iran hostage crisis.) Similarly, if R possesses threat power, it can threaten to choose its second strategy—giving C a choice between (3,3) and (1,1)—and thereby compel the choice of (3,3). Note that these are the same outcomes that moving power induces for the two players.

But this coincidence of power-induced outcomes in game #56 does not obtain in other games. Sometimes, for example, one kind of power is effective in a game but another kind is not. Other times only one kind of power is defined in a game, as we shall illustrate in the Iran hostage crisis. Moreover, when power does manifest itself, it may do so in different forms. Hence, it may be necessary to use different concepts of power to model the effects of different asymmetries in capabilities, underscoring power's multidimensional character.

MISPERCEPTION IN THE IRAN HOSTAGE CRISIS

In the Iranian seizure of American embassy hostages in November 1979, the military capabilities of the two sides were almost irrelevant. Although an attempt was made to rescue the hostages in an aborted U.S. military operation in April 1980 that cost eight American lives, the conflict was never really a military one. It can best be represented as a game in which President Jimmy Carter misperceived the preferences of Ayatollah Ruholla Khomeini and attempted, quite desperately, to find a solution in the wrong game.

Why did Khomeini sanction the takeover of the American embassy by militant students? It had two advantages. First, by creating a confrontation with the United States, Khomeini was able progressively to sever the many links that remained with this "Great Satan" from the days of the Shah. Second, the takeover mobilized opinion behind extremist revolutionary objectives just at the moment when moderate secular elements in Iran were challenging the principles of the theocratic state that Khomeini had installed.

President Carter most wanted to obtain the immediate release of the hostages. His secondary goal was to hold discussions with Iranian religious authorities on resolving the differences that had severely strained U.S.-Iranian relations. Of course, if the hostages were killed, the United States would defend their honor, probably by a military strike against Iran.

Carter considered two strategies:

1. *Negotiate (N).* With diplomatic relations broken after the seizure, negotiations could be pursued through the U.N. Security Council,

the World Court, or informal diplomatic channels; the negotiations might involve the use of economic sanctions.

2. *Intervene militarily (I).* Military action could include a rescue mission to extract the hostages or punitive strikes against selected targets (e.g., oil refineries, rail facilities, or power stations).

Khomeini also had two strategies:

1. *Negotiate (N).* Negotiations would involve demanding a return of the Shah's assets and an end to U.S. inference in Iran's affairs.
2. *Obstruct (O).* Obstructing a resolution of the crisis could be combined with feigning to negotiate.

Carter's view of the game is shown in the top matrix of Figure 3,

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Figure 3 about here

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which is game #50. He most preferred that Khomeini choose N (4 and 3) rather than O (2 and 1), but in either case he preferred N to O, given the difficulties of military intervention.

These difficulties were compounded in December 1979 by the Soviet invasion of Afghanistan, which eliminated the Soviet Union as a possible ally in seeking concerted action for release of the hostages through the United Nations. With Soviet troops next door in Afghanistan, the strategic environment was anything but favorable for military intervention.

As for Khomeini, Carter *thought* that he faced serious problems within Iran because of a critical lack of qualified people; demonstrations by the unemployed; internal war with the Kurds; Iraqi incursions across Iran's western border; and a continuing power struggle at the top (though his own

Figure 3

Iran Hostage Crisis (Games #50 and #5)

Game as Misperceived by Carter (Game #50)

Khomeini

Carter	Negotiate (N)		Obstruct (O)	
Negotiate (N)	I. Compromise (4,3) [4,3]	→	II. Carter surrenders (2,4) [4,3]	← Dominant strategy
	↑		↓	
Intervene militarily (I)	IV. Khomeini surrenders (3,2) [4,3]/[2,4]	←	III. Disaster (1,1) [2,4]/[4,3]	

Real Game (Game #5)

Khomeini

Carter	Negotiate (N)		Obstruct (O)	
Negotiate (N)	I. Carter succeeds (4,2) [2,4]	→	II. Khomeini succeeds (2,4) [2,4]	← Dominant strategy
	↑		↓	
Intervene militarily (I)	IV. Carter adamant (3,1) [2,4]	←	III. Khomeini adamant (1,3) [2,4]	
			↑ Dominant strategy	

Key: (x,y) = (payoff to Carter, payoff to Khomeini)

[x,y] = [payoff to Carter, payoff to Khomeini] in anticipation game (AG)

4 = best; 3 = next best; 2 = next worst; 1 = worst

Nash equilibria in original games underscored

NMEs circled

Arrows indicate direction of cycling

authority was unchallenged). Consequently, Carter believed that negotiations would give Khomeini a dignified way out of the impasse (Carter, 1982, pp. 459-489).

One implication of this view is that while Carter thought that Khomeini most preferred a U.S. surrender at NO (4), he would next most prefer the compromise of NN (3). Thus, Khomeini's two worst states (1 and 2), in Carter's view, were associated with the U.S.'s strategy of M.

Carter's imputation of these preferences to Khomeini turned out to be a major misperception of the strategic situation. Khomeini wanted the total Islamization of Iranian society; the United States was a "global Shah—a personification of evil" (as quoted in Saunders, 1985, p. 102) that had to be cut off from any contact with Iran. Khomeini abjured his nation never to "compromise with any power . . . [and] to topple from the position of power anyone in any position who is inclined to compromise with the East and West" (Sick, 1985a, p. 237).

If Iran's leaders should negotiate the release of the hostages, this would weaken their uncompromising position. Those who tried, including President Bani-Sadr and Foreign Minister Ghotbzadeh, lost in the power struggle. Bani-Sadr was forced to flee for his life to Paris, and Ghotbzadeh was arrested and later executed.

What Carter was unable to grasp was that Khomeini most preferred O (4 and 3), independent of what the United States did. Doubtless, Khomeini also preferred that the United States choose N, whatever his own strategy choice was, giving him the preferences shown in the bottom matrix of Figure 3, which is game #5.

Perhaps the most salient difference between "Carter's game" (game #50) and the "real game" (game #5) is that the former game contains two

NMEs, (4,3) and (2,4), whereas the latter game contains only one, (2,4). In Carter's game, his preferred solution of compromise at (4,3) can be reached wherever play commences, as is evident from its anticipation game (AG).

In addition, (4,3) is the outcome whichever player possesses moving power. To see this, note that game #50 is cyclic in clockwise direction (Figure 3). If Carter possesses moving power, he can force Khomeini to choose between (4,3) and (1,1), where Khomeini has the next move; if Khomeini possesses moving power, he can force Carter to choose between (2,4) and (3,2), where Carter has the next move. Although Carter would prefer (3,2), it is in both players' interest to agree to the Pareto-superior (4,3), making this state the common choice of the players if one player, according to rule 5', induces cycling.

On the other hand, threat power is effective. Carter has a *deterrent threat:* by threatening the choice of I, which leads to Khomeini's two worst states (giving him payoffs of 1 and 2), Carter can induce the choice of (4,3), which is better for both players than either (3,2) or (1,1) associated with strategy I. Like the threats of both players in game #56, Khomeini's threat is compellent: by refusing to move from O, he can induce Carter to choose N, leading to (2,4).

Thus, the possessor of threat power can implement its best outcome, as can the possessor of order power, starting from either (3,2) or (1,1) (see Figure 3).[18] Insofar as Carter believed that he had the upper hand in game #50, therefore, he would see compromise as attainable.

The prospects for compromise are very different in the real game (game #5). Not only is (2,4) the unique NME, favoring Khomeini, but

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[18]In the case of order power, each player would prefer to be P1 from (3,2), but P2 from (1,1).

Khomeini can induce it with a compellent threat by staying at O. By contrast, Carter does not have a threat strategy in this game. Furthermore, though game #5 is cyclic in a clockwise direction (Figure 3), moving power is not defined in it for reasons discussed in Brams (1992, ch. 5). But because Carter thought he was playing game #50, in which the (4,3) NME can always be induced if play starts at either state associated with N, Carter would have no reason not to choose N.

Adopting this strategy from the start turned out to be a blunder. However, in the game as he perceived it, Carter also had a deterrent threat (noted earlier), which he pursued as well. He dispatched the aircraft carrier USS Kitty Hawk and its supporting battle group from the Pacific to the Arabian Sea. The carrier USS Midway and its battle group were already present in the area. Sick (1985b, p. 147) reported:

> With the arrival of Kitty Hawk, the United States had at its disposal the largest naval force to be assembled in the Indian Ocean since at least World War II and the most impressive array of firepower ever deployed to those waters.

But this threat, like those preceding it, did not lead to any change in Khomeini's strategy because of Carter's fateful underestimation of Khomeini's willingness and ability to absorb economic, political, and military punishment in the pursuit of his revolutionary goals. Military intervention in Iran (I) leads to the (1,3) state when Khomeini chooses obstruct (O). Because of the possible execution of the hostages that this attack might provoke—the threat of which was "taken with deadly seriousness in Washington" (Sick, 1985b, p. 147)—we rank it as worst for the United States.

After negotiations faltered and then collapsed in April 1980, Carter was forced to move to his I strategy. If the rescue operation had succeeded and the hostages had been freed, the game would have been in state (3,1), because Khomeini could in that situation no longer use the hostages as a weapon and choose O.

The rescue's failure kept the situation in state (4,2) for another nine months. But the Iranian leadership had already concluded in August 1980, after the installation of an Islamic government consistent with Khomeini's theocratic vision, that the continued retention of the hostages was a net liability (Saunders, 1985, pp. 44-45). Further complicating Iran's position was the attack by Iraqi forces in September 1980. It was surely no accident that the day of Carter's departure from the White House on January 20, 1981, 444 days after the capture of the hostages, they were set free.[19]

Although Carter's strategic acumen in this crisis can be questioned, it was less his rationality that was at fault as his misperception of Khomeini's preferences. Within a week of the embassy seizure, analysts in the State Department had reached the conclusion that

> diplomatic action had almost no prospect of being successful in liberating the hostages and that no economic or other U.S. pressure on the Iranian regime, including military action, was likely to be any more successful in securing their safe release. Consequently, they concluded, the detention of the hostages could continue for some months (Sick, 1985a, p. 246).

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[19]That the hostages were not released before the November 1980 presidential election, which clearly would have benefited Carter's bid for reelection, Sick (1991) attributes to a secret deal Iran made with Reagan supporters. But this allegation, at least as far as George Bush's involvement is concerned, is disputed by a bipartisan October Surprise Task Force of the U.S. House of Representatives (Lewis, 1992).

In the first few months of the crisis, U.S. Secretary of State Cyrus Vance counseled that "we continue to exercise restraint" (Vance, 1983, p. 408). Privately, he vehemently opposed any military action and, after the military rescue operation failed, he resigned.

But others voiced different views, including secular politicians in Iran who claimed to speak for Khomeini. There was an abundance, rather than a dearth, of information, but the question, as always, was what was accurate. Carter, perhaps, should not be judged too harshly for misjudging the situation. In fact, even if he had foreseen the real game from the start, this analysis suggests that there was little that he could do to move the state away from (2,4), given that the military power of the United States could not readily be translated into a credible threat.

Nevertheless, Carter's misperception gave him the hope that he could implement the compromise outcome in game #50 not only because it is an NME but also because it can be induced via threat power or order power. By contrast, the compromise outcome in game #5 is not an NME, and no kind of power can induce it.

This contrast between the two games is obscured by the classical theory, which shows (2,4), in which Carter surrenders, to be the unique Nash equilibrium, associated with Carter's dominant strategy of N, in each game. Thus, the classical theory makes Carter's actions inexplicable in terms of rational choice—whether he misperceived Khomeini's preferences or not—whereas TOM shows that Carter's actions, given his misperception, were not ill-founded.

CONCLUSION

A feature of TOM we singled out at the outset is the distinctive point of view that it provides. Among other things, the theory is *ordinal:* it assumes no quantitative calculations, based on cardinal utilities or probabilities that can be used to define expected values, which are intrinsically unmeasurable. Also, play starts in a state, not with strategy choices or announcements, except when threats are used.

To be sure, utilities and quantitative calculations have their place, but not usually as a first approximation in analyzing questions of strategy. Rather, there seem to me more fundamental strategic issues, tied to the following three concepts:

1. Stability. An NME is the basic equilibrium concept used, under the assumption that most real-life players are not as myopic—especially when they make important decisions—so as to consider only the effects of an immediate departure from a state, without taking into account possible responses of other players as well as themselves. At the same time, players may contemplate the possibility of cycling back to the initial state, which NMEs prohibit, in an effort to outlast an opponent. In fact, we relaxed the prohibition against cycling to analyze cyclic games, in which termination may depend on which player, if either, possesses moving power.

2. Power. Many if not most games are between players with different capabilities, so it is appropriate to consider different kinds of asymmetries that may occur in their play. Moving, order, and threat power reflect, respectively, the ability to hold out longer in a continuing conflict, to determine who moves first from an indeterminate state, and to choose a strategy that will compel or deter untoward future choices when a game is repeated. These different kinds of power may single out one NME over others.

3. Information. Players may not have complete information about either an opponent's preferences or its power (relative to theirs), so it is important to analyze the effects of incomplete information on the play of a game. We gave an example of how a lack of information led to misperception, illustrating how levels of information can be incorporated into the TOM analysis. Normatively speaking, this analysis may help players determine whether they can make rational strategy choices without acquiring additional information or should, instead, search for such information.

Viewed through the lenses of these three concepts, TOM addresses central issues in a parsimonious fashion. Grounded in only a few rules of play, its theoretical foundations are simple but generate a host of consequences.

For the practitioner, especially, our catalogue of the properties of all the 2 x 2 conflict games given in the Appendix should help in determining whether, for example, threats in a particular game are effective, and if so what kind. One cannot understand the properties of larger games until the intricacies of 2 x 2 games have been thoroughly explored.

We are ambivalent about extending the analysis to more complex games. Certainly backward induction can be carried out quickly on a computer, although it would take some effort to develop an efficient algorithm for making nonmyopic calculations in larger matrix games. But do people really think through the manifold choices in larger games? And do they follow the rules of play that we postulated?

There is no science for formulating "best" rules. This problem falls in the realm of modeling, which is more an art than a science. It relies on good intuition and a familiarity with the strategic choices in empirical situations one is trying to explain. We urge a continuing dialogue between theory and applications to motivate further theoretical refinements and test the empirical validity of the theory.

APPENDIX

There are 78 structurally distinct 2 x 2 strict ordinal games in which the two players, each with two strategies, can strictly rank the four states from best to worst. These games are "distinct" in the sense that no interchange of the column player's strategies, the row player's strategies, the players, or any combination of these can transform one game into any other. That is, these games are structurally different with respect to these transformations.

Of the 78 games, 21 are no-conflict games with a mutually best (4,4) state. These states are always Nash and nonmyopic equilibria (NMEs) in these games; no kind of power—moving, order, or threat—is needed by either player to implement them as outcomes.

We list here the remaining 57 games, in which the players disagree on a most-preferred state. The numbers used in the original listing of the 78 games by Rapoport and Guyer (1966) are given in parentheses after the numbers used here.[20] The 57 games are divided into three main categories: (i) those with one NME (31 games), (ii) those with two NMEs (24 games), and (iii) those with three NMEs (2 games). We have grouped together at the end of the list the nine games with indeterminate states—seven of which fall in category (ii) and two of which fall in category (iii)—in which order power is effective when play starts at an indeterminate state.

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[20]Another complete listing of the 78 games is given in Brams (1977), in which the games are divided into three categories based on their vulnerability to deception. The moving-power outcomes identified in the 57 conflict games listed in Brams (1982a, 1983) differ somewhat from those given here because of changes we have made in the rules of play of TOM. Threat-power outcomes were previously identified in Brams (1983, 1990) and Brams and Hessel (1984). Order power is a new concept, which we use instead of staying power (Brams, 1983; Brams and Hessel, 1983; Kilgour, De, and Hipel, 1987) for reasons given in the text.

Moving and threat power outcomes that row and column can induce are indicated by the superscripts in the key given below. (Outcomes that can be induced by order power in games with indeterminate states are also identified in the key.) If the outcomes induced by moving or threat power are different, then this power is effective—the player who possesses it can induce a better outcome for itself than if the other player possessed it. All games in which there is a moving power outcome, whether moving power is effective or not, are cyclic. All other games are noncyclic, except games #5, #25, and #26, which are cyclic but in which moving power is not defined for reasons given in Brams (1992, ch. 5).

The key to the symbols is as follows:

(x,y) = (payoff to row, payoff to column)

[a,b] = [payoff to row, payoff to column] in anticipation game (AG)

[w,x]/[y,z] = indeterminate state in AG, where [w,x] is the NME induced if row has order power, [y,z] if column has order power, from corresponding state in original game

4 = best; 3 = next best; 2 = next worst; 1 = worst

Nash equilibria in original game and AG underscored (except when there is only one NME in AG)

NMEs in original game circled

m/M = moving-power outcome row/column can induce

t/T = threat-power outcome row/column can induce

c/d = compellent/deterrent threat outcome

31 Games with One NME

1 (13)

(3,4)mMTc	(4,2)
(2,3)	(1,1)

2 (14)

(3,4)mMTc	(4,2)
(1,3)	(2,1)

3 (15)

(3,4)mMTc	(4,1)
(2,3)	(1,2)

4 (16)

(3,4)mMTc	(4,1)
(1,3)	(2,2)

5 (17)

(2,4)Tc	(4,2)
(1,3)	(3,1)

6 (18)

(2,4)MTc	4,1)
(1,3)	(3,2)m

7 (7)

(3,3)mM	(4,2)
(2,4)	(1,1)

8 (8)

(3,3)	(4,2)
(1,4)	(2,1)

9 (9)

(3,3)	(4,1)
(1,4)	(2,2)

10 (10)

(2,3)	(4,2)
(1,4)	(3,1)

11 (11)

(2,3)	(4,1)
(1,4)	(3,2)

12 (40)

(3,4)mMTc	(4,1)
(2,2)	(1,3)

13 (41)

(3,4)mMTc	(4,1)
(1,2)	(2,3)

14 (31)

(3,4)Tc	(2,2)
(1,3)	(4,1)

15 (32)

(3,4)Tc	(2,1)
(1,3)	(4,2)

16 (33)

(3, 4)Tc	(1,2)
(2,3)	(4,1)

17 (34)

(3,4)Tc	(1,1)
(2,3)	(4,2)

18 (35)

(2,4)Tc	(3,2)
(1,3)	(4,1)

19 (36)

(2,4)Tc	(3,1)
(1,3)	(4,2)

20 (37)

(3,4)Tc	(2,3)
(1,2)	(4,1)

21 (38)

(3,4)Tc	(1,3)
(2,2)	(4,1)

22 (39)

(2,4)Tc	(3,3)td
(1,2)	(4,1)

23 (42)

(3,3)mMTc	(4,1)
(2,2)	(1,4)

24 (43)

(3,3)mMTc	(4,1)
(1,2)	(2,4)

25 (45)

(3,2)	(4,1)
(2,3)	(1,4)

26 (46)

(3,2)	(4,1)
(1,3)	(2,4)

27 (47)

(2,3)	(4,1)
(1,2)	(3,4) mMTd

28 (48)

(2,2)	(4,1)
(1,3)	(3,4) mMTd

29 (72)

(3,2)	(2,1)
(4,3) mMtdTc	(1,4)

30 (77)

(2,2)	(4,1)
(3,3) mMtdTc	(1,4)

31 (78)

(2,2)	(3,1)
(4,3) mMtdTc	(1,4)

24 Games with Two NMEs

32 (12)

(2,2) [2,2]	(4,1) [3,3]
(1,4) [3,3]	(3,3) dTd [3,3]

33 (19)

(3,4) MTc [3,4]	(4,3) mtd [4,3]
(1,2) [3,4]	(2,1) [3,4]

34 (20)

(3,4) MTc [3,4]	(4,3) mtd [4,3]
(2,2) [3,4]	(1,1) [3,4]

35 (21)

(2,4) Tc [2,4]	(4,3) mMtd [4,3]
(1,2) [2,4]	(3,1) [2,4]

36 (49)

(3,4) MTc [3,4]	(4,3) mtd [4,3]
(2,1) [3,4]	(1,2) [3,4]

37 (50)

(3,4) MTc [3,4]	(4,3) mtd [4,3]
(1,1) [3,4]	(2,2) [3,4]

38 (51)

(3,4) MTc [3,4]	(4,2) m [4,2]
(2,1) [3,4]	(1,3) [3,4]

39 (52)

(3,4) MTc [3,4]	(4,2) m [4,2]
(1,1) [3,4]	(2,3) [3,4]

40 (53)

(3,3) MTc [3,3]	(4,2) m [4,2]
(2,1) [3,3]	(1,4) [3,3]

41 (54)

(3,3) MTc [3,3]	(4,2) m [4,2]
(1,1) [3,3]	(2,4) [3,3]

42 (73)

(2,4) M [2,4]	(4,1) [3,2]
(3,2) m [3,2]	(1,3) [2,4]

43 (74)

(2,4) M [2,4]	(3,1) [4,2]
(4,2) m [4,2]	(1,3) [2,4]

44 (75)

(2,3)^{M} [2,3]	(4,1) [3,2]
(3,2)^{m} [3,2]	(1,4) [2,3]

45 (76)

(2,3)^{M} [2,3]	(3,1) [4,2]
(4,2)^{m} [4,2]	(1,4) [2,3]

46 (70)

(3,4)^{Mtc} [3,4]	(2,1) [4,2]
(4,2)^{m} [4,2]	(1,3) [3,4]

47 (71)

(3,3)^{MtcTd} [3,3]	(2,1) [4,2]
(4,2)^{Mm} [4,2]	(1,4) [3,3]

48 (57)

(2,3) [3,4]	(4,2)^{m} [4,2]
(1,1) [3,4]	(3,4)^{MTd} [3,4]

9 Games with Indeterminate States

49 (44)

(2,4)^{Tc} [3,3]	(4,1) [2,4]
(1,2) [2,4]/[3,3]	(3,3)^{mMtc} [2,4]

50 (55)

(2,4)^{Tc} [4,3]	(4,3)^{mMtd} [4,3]
(1,1) [2,4]/[4,3]	(3,2) [4,3]/[2,4]

51 (64)

(3,4)^{Tc} [4,3]	(2,1) [3,4]/[4,3]
(1,2) [3,4]/[4,3]	(4,3)^{tc} [3,4]

52 (65)

(2,4)^{Tc} [4,3]	(3,1) [4,3]/[2,4]
(1,2) [2,4]/[4,3]	(4,3)^{tc} [2,4]

53 (67)

(2,3) [3,4]/[4,2]	(3,4)^{Tc} [4,2]
(4,2)^{tc} [3,4]	(1,1) [3,4]/[4,2]

54 (68)

(2,2) [3,4]/[4,3]	(3,4)^{Tc} [4,3]
(4,3)^{tc} [3,4]	(1,1) [3,4]/[4,3]

55 (69)

(2,2) [3,4]/[4,3]	(4,3)^{tc} [3,4]
(3,4)^{Tc} [3,4]	(1,1) [3,4]/[4,3]

2 Games with Three NMEs

56 (56)

(2,4)Tc [3,3]	(4,2)m [4,2]
(1,1) [2,4]/[3,3]	(3,3)Mtc [2,4]

57 (66)

(3,3) [3,3]	(2,4)Tc [4,2]/[3,3]
(4,2)tc [3,3]/[2,4]	(1,1) [2,4]/[4,2]

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